THE JOURNAL and CERAMIC ABSTRACTS

AMERICAN CERAMIC SOCIETY

OCTOBER • 1939

MONTHLY PUBLICATION DEVOTED TO THE ARTS AND SCIENCES RELATED TO THE SILICATE INDUSTRIES

TABLE OF CONTENTS

Vol. 22 October, 1939 No. 10

THE JOURNAL

The Series Iron Oxides–Lime 313
By Welton J. Crook

The Series Iron Oxides–Silica 322
By Welton J. Crook

A Critical Examination of the Load Test for Refractories 334
By F. H. Norton

Observations on the Slagging of Some Glass Furnace Checkers 337
By W. L. Fabianic

Thermochemistry of North Carolina Olivine in the Manufacture of Forsterite Refractories 342
By Robert L. Stone

Some Sheet-Iron Enamel Defects Traceable to the Base Metal or Metal Forming Operation 348
By E. E. Howe

A Laboratory Slagging-Test Furnace with a Rotating Burner 354
By R. K. Hursh

CERAMIC ABSTRACTS

18—10

Abrasives 261
Art and Archeology 262
Cements 264
Enamel 265
Glass 266
Structural Clay Products 269
Refractories 269
Terra Cotta 272
Whiteware 273
Equipment and Apparatus 274
Kilns, Furnaces, Fuels, and Combustion 277
Geology 278
Chemistry and Physics 281
General 283

Publication Office: 20th & Northampton Sts., Easton, Pa.
Editorial Office: 2525 N. High St., Columbus, Ohio
Entered as second-class matter at the post office at Easton, Pa., under the act of March 3, 1879. Published monthly.
Subscription fifteen dollars ($15.00) a year. Single numbers $1.50
(Foreign and Canadian postage, 50¢ additional on subscriptions)
(Copyright 1939, American Ceramic Society, Inc.)

THE SERIES IRON OXIDES–LIME*

By Welton J. Crook

Abstract

The literature in general shows a considerable divergence of opinion regarding the basicity of the ferrite formed in steelmaking slags. Evidence is presented which indicates that when mixtures of iron oxide and lime are melted under oxidizing conditions in contact with metallic iron a ternary system between CaO–FeO–Fe_2O_3 prevails and that the compound formed between lime and ferric oxide has the composition $3CaO \cdot Fe_2O_3$, except possibly for melts containing somewhat less than 10 mol.% CaO.

A eutectic was found between FeO and $3CaO \cdot Fe_2O_3$, which contains approximately 40 mol.% CaO.

It is believed that when basic steelmaking slags are considered, the ternary system CaO–FeO–Fe_2O_3 should be substituted for the binary system CaO–Fe_2O_3, which has been used generally in the past.

I. Introduction

A study of the "mineralogy" and chemistry of the general series iron oxides–silica–lime, particularly as related to steelmaking slags, has been carried on by the writer for several years. The results recorded in this paper have to do with experimental slag melts lying on the FeO–Fe_2O_3–CaO face of the representative tetrahedron of the general series. It is a continuation of work previously recorded.[1]

(1) Literature Review

Apparently, the first recorded work of any importance on the lime ferrites is that of Hilpert and Kohlmeyer,[2] who believed that lime formed five compounds with ferric oxide. The existence of many of these compounds, however, has not been substantiated by later workers. Sosman and Merwin[3] found only two compounds in the series CaO–Fe_2O_3, the mono- and di-ferrites. Yasuirkin[4] determined the heats of formation of four calcium ferrites, *viz.*, $2CaO \cdot Fe_2O_3$, $4CaO \cdot Fe_2O_3$, $CaO \cdot Fe_2O_3$, and $3CaO \cdot Fe_2O_3$; from these data, Herty[5] assumed that the most stable compound is $2CaO \cdot Fe_2O_3$; Ferguson,[6] using both chemical and petrographic methods of determination, found crystals of tribasic ferrite (and tricalcic silicate) in open-hearth slags.

Nagai and Asaoka[7] showed that tricalcium ferrite decomposes into $2CaO \cdot Fe_2O_3$ and that the diferrite is the stable compound at high temperature. Herty[8] studied a series of slags from high carbon heats and found that the ratio Fe_2O_3 to FeO increases regularly with increasing basicity. He concluded, therefore, that some Fe_2O_3 in the slag combines with lime as $2CaO \cdot Fe_2O_3$. With zero basicity, the Fe_2O_3 to FeO ratio is 0.2, and any Fe_2O_3 above this ratio is considered as combining with lime. Herty also found that by the time ore is added or worked through the slag, sufficient lime is in solution, and the formation of calcium ferrite begins. An increase in CaO concentration in the slag was accompanied by an increase in Fe_2O_3, presumably as a result of the formation of stable lime-iron oxide compounds.

Salmang and Kaltenbach[8] confirmed Herty's ideas that CaO favors the formation of ferric oxide and that silica tends to form ferrous oxide.

In the discussion of a paper by Quadrat,[9] several facts were given to support the contention that Fe_2O_3 acts as an acid in basic slags. In this discussion, Colclough[10] stated that ferric oxide is capable of forming stable compounds of the spinelloid type. He also supported the view that under certain conditions Fe_2O_3 is definitely in combination with lime. In a discussion of this same paper (Quadrat), Ferguson[6] reported that he had obtained crystals in basic slags with the silica content not exceeding 12%. These crystals had a flat needle form with a barrel-shaped outline. They were nonmagnetic, with a density of about 4.

---

* Presented at the Golden Gate General Meeting, American Ceramic Society, San Francisco, Calif., August 6–12, 1939. Received November 10, 1938.

[1] W. J. Crook, "Recherches Expérimentales sur la Constitution Minéralogique et sur l'Action Chemique des Scories de l'Élaboration de l'Acier," École Polytechnique "Roi Carol II," Bucharest, 1936.

[2] S. Hilpert and E. G. Kohlmeyer, "Über Calcium Ferrite," *Ber. deut. chem. Ges.*, **42**, 4581–94 (1909).

[3] R. B. Sosman and H. E. Merwin, "Preliminary Report on System Lime–Ferric Oxide," *Jour. Wash. Acad. Sci.*, **6**, 532–37 (1916).

[4] N. M. Yasuirkin, "Heat of Formation of Ferrates of Calcium," *Annal. École Super. Agr. Amelioration.* [Don, Russia], **6**, 57–60 (1925).

[5] C. H. Herty, *et al.*, "Control of Iron Oxide in Basic Open-Hearth Process," *Carnegie Inst. Tech., Coöp. Bull., Mining Met. Invest.*, No. 68 (1934).

[6] J. M. Ferguson, "Notes on Basic Open-Hearth Process," *Jour. West Scot. Iron Steel Inst.*, **42**, 13–23 (1934); *Ceram. Abs.*, **14** [9] 232 (1935).

[7] S. Nagai and K. Asaoka, "Studies on Calcium Ferrites and Iron Cements, I," *Jour. Soc. Chem. Ind.* [Japan], **33** [4] 130–33B (1930); *Ceram. Abs.*, **10** [4] 251 (1931).

[8] H. Salmang and J. Kaltenbach, "Degree of Oxidation of Iron in Slags in Relation to Chemical Composition, Temperature, and Furnace Atmosphere," *Arch. Eisenhüttenw.*, **8**, 9–13 (1934); *Ceram. Abs.*, **13** [11] 303 (1934).

[9] O. Quadrat, "Contribution to Problem of Analysis of Basic Slags," *Jour. Iron Steel Inst.* [London], **122** [2] 175–90 (1930).

[10] T. P. Colclough, discussion of Quadrat, footnote 9.

Some of them were isolated in a high state of purity from cavities in the slag. Their analysis gave SiO_2 1.08%, Al_2O_3 1.36%, Fe_2O_3 44.04%, MnO 4.43%, CaO 44.16%, and MgO 4.48%. He calculated that the molecular ratio of CaO to Fe_2O_3 is 2.89 to 1, and he concluded that the compound, $3CaO \cdot Fe_2O_3$, is present.

Colclough's assumption is not believed to be justified because of the complex nature of his material. The writer has recalculated the analysis upon the basis that the SiO_2, Al_2O_3, and MnO do not unite with the Fe_2O_3, CaO, and MgO and that the MgO may be added to the CaO in molecular proportions (previous experience has shown the latter to be justified). When this is done, the molecular ratio, Fe_2O_3 to CaO+MgO, is 1 to 3.21.

In a paper on the fusibility of mixtures of Fe_2O_3 and CaO, Jacqué[11] found that Fe_2O_3 was partly decomposed in nonoxidizing atmospheres with the formation of magnetite. Konarzewski[12] found that Fe_2O_3 evolves O_2 at 1380°C, yielding Fe_3O_4 in which it forms solid solutions. He found two compounds in the system CaO–Fe_2O_3, *viz.*, $2CaO \cdot Fe_2O_3$ (melting point 1440°C) and $CaO \cdot Fe_2O_3$ (melting point 1215°C). He found, furthermore, that calcium ferrites are formed from $CaCO_3$ and Fe_2O_3 mixtures at temperatures below 500°C; the reaction takes place in the solid phase and the velocity is given by the equation, $y^2 = kt$, where y = % transformation and t = time. The effect of temperature is given by $k = e^{B-QA/RT}$. A curve connecting log y with t consists of two intersecting straight lines. He considered this to be due to the fact that at low temperatures $CaCO_3$ reacts directly with Fe_2O_3, and above 900°C CaO is formed, which also reacts with Fe_2O_3. The velocity of reaction depends upon the degree of comminution of the components. He stated that water has little action on $2CaO \cdot Fe_2O_3$, and that this compound does not decompose below 1400°C.

There are a number of references to the fact that all ferrites are ferromagnetic. In this connection, Hilpert and Wille[13] found that the magnetizability is at a maximum for the molecular ratio, $2MO \cdot 3Fe_2O_3$. They state that the ferromagnetism of ferrites depends upon the presence of Fe_2O_3 acting as an acid and that ferromagnetism seems to have no connection with lattice structure, being purely a molecular or atomic property.

The most usually accepted constitutional diagram of the series CaO–Fe_2O_3 is that of Sosman and Merwin[3] (see Fig. 1). They melted small charges (1 to 2 grams) in platinum crucibles, using C.P. $CaCO_3$ and Fe_2O_3. Mixtures containing less than 50 mol. % CaO were not heated above 1250°C in order to avoid the dissociation of Fe_2O_3. The heating presumably was carried on in air. No analyses of the slags produced were recorded in the paper; it is presumed that because of the small melts produced the analyses were not made. It is stated, however, that a certain amount of ferrous iron was present in all the melts; this amount is small in mixtures heated from 1400° to 1500°C, but it increases rapidly (with increase in temperature and in Fe_2O_3) in melts from 0 to 50 mol. % CaO. The authors state that some of the melting and solidifying points observed probably belong to the three-component system, CaO–Fe–O. Sosman and Merwin observed only two binary compounds in the system CaO–Fe_2O_3, *viz.*, $CaO \cdot Fe_2O_3$ and $2CaO \cdot Fe_2O_3$, both of which appeared to dissociate at their melting points. The properties of $2CaO \cdot Fe_2O_3$ were as follows: The compound crystallizes well, giving black crystals that are yellowish-brown by transmitted light. The crystallized product shows, upon undercooling to 1385°C or lower, traces of free CaO and $CaO \cdot Fe_2O_3$, which are due to dissociation. They found that the compound could be formed from fine powder mixtures of $CaCO_3$ and Fe_2O_3 at temperatures below the melting point. No evidence of solid solution of CaO or $CaO \cdot Fe_2O_3$ in $2CaO \cdot Fe_2O_3$ was found.

The compound, $CaO \cdot Fe_2O_3$, is described by Sosman and Merwin as crystals with a black color which are deep red by transmitted light, about like hematite, nearly or quite uniaxial, negative. No optical evidence of solid solution either of $2CaO \cdot Fe_2O_3$ or Fe_2O_3 in the compound was found. It is interesting to note that Sosman and Merwin found no evidence of the existence of the compound, $3CaO \cdot Fe_2O_3$. Samples of this composition gave only CaO and $2CaO \cdot Fe_2O_3$.

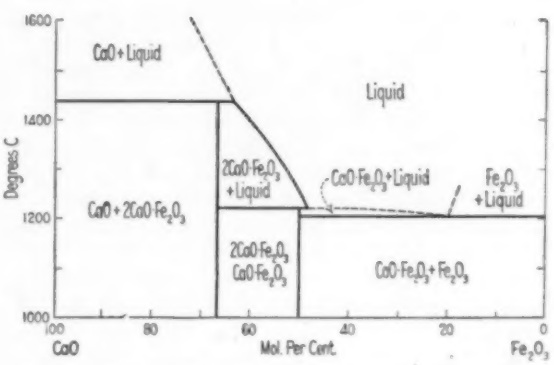

FIG. 1.—System CaO–Fe_2O_3 (not a true binary system) (R. B. Sosman and H. E. Merwin, *Jour. Wash. Acad. Sci.*, **6**, 532–37 (1916); p. 534).

The writer,[1] using magnesite crucibles, found that when heating mixtures of lime and ferric oxide at 1600°C no evidence of the presence of the compound $3CaO \cdot Fe_2O_3$ could be found on microscopic examination of the melts. Slags, containing a molecular ratio of CaO (+MgO) to Fe_2O_3 greater than 2 to 1, showed the presence of crystallized lime. In all cases, some FeO was produced. For instance, slag No. 56 contained (in mol. %) SiO_2 trace, FeO 6.52, Fe_2O_3 28.93, and CaO 64.55. Another slag (No. 77) contained (in mol. %) SiO_2 0.58, FeO 12.84, Fe_2O_3 13.05, CaO 69.04, and MgO 4.49. It was found that when lime was replaced by magnesia the optical appearance of the resulting

[11] L. Jacqué, "Sur la Fusibilité des Mélanges Ferro-Calciqués," *Compt. Rend.*, **188**, 917–19 (1929).

[12] J. Konarzewski, "Compounds of CaO–Fe_2O_3 System and Their Rôle in Portland Cement," *Roczniki Chem.*, **11** [6] 516–28, 607–35 (1931); *Chim. & Ind.*, **27** [1] 104 (1932); *Ceram. Abs.*, **11** [8] 441 (1932).

[13] S. Hilpert and A. Wille, "Connection between Ferro-Magnetism and Structure of Ferrites," *Z. physik. Chem.*, **B18**, 219–315 (1932).

slags was closely similar to that of slags prepared with CaO.

A considerable divergence of opinion seems to be recorded in the literature concerning the compounds formed between iron oxide and lime. No mention was found of the existence of any compounds between CaO and FeO, except that Martin and Vogel[14] claim to have found two ternary compounds corresponding to the formulas $(CaO)_4(Fe_3O_4)_3$ and $(FeO)_9CaO$. The various opinions regarding the compounds formed between lime and ferric oxide are summarized in Table I.

It is interesting to note that in nearly all cases encountered in the literature where the compound, $3CaO \cdot Fe_2O_3$, is described the slags were melted or formed in contact with iron. In cases where metallic iron was absent, the tricalcium ferrite was said to be absent.

One of the objects of the present work was to determine, if possible, whether or not the presence of metallic iron during melting is responsible for the production of the triferrite. The well-known effect of metallic iron in reducing ferric oxide to ferrous oxide in iron-oxide melts would offer some possibility of the production of $3CaO \cdot Fe_2O_3$, where a deficiency of Fe_2O_3 existed. In the case of melts made in the absence of iron, large quantities of ferric oxide are available to the lime for the formation of the diferrite.

TABLE I

Compound	Author*	Remarks
Calcium ferrite	Quadrat[9]	Considers Fe_2O_3 in basic slag to be in form of calcium ferrite
$2CaO \cdot Fe_2O_3$	Herty[5]	Considers this to be stable compound and present in steelmaking slags
$2CaO \cdot Fe_2O_3$	Martin[15]	Obtained by heating CaO and Fe_2O_3 just below melting point
$3CaO \cdot Fe_2O_3$	Ferguson[6]	Found in basic open-hearth slags
$2CaO \cdot Fe_2O_3$	Nagai and Asaoka[7]	$3CaO \cdot Fe_2O_3$ decomposes to $2CaO \cdot Fe_2O_3$, which is stable compound
$3CaO \cdot Fe_2O_3$	Colclough[10]	Nonmagnetic; isolated from basic open-hearth slags containing not more than 12% SiO_2
$2CaO \cdot Fe_2O_3$ and $CaO \cdot Fe_2O_3$	Sosman and Merwin[3]	From melts made in Pt crucibles
$2CaO \cdot Fe_2O_3$ and $CaO \cdot Fe_2O_3$	Konarzewski[12]	Gives melting point for $2CaO \cdot Fe_2O_3$ as 1440°C and for $CaO \cdot Fe_2O_3$ as 1215°C; $2CaO \cdot Fe_2O_3$ does not decompose below 1400°C

* See footnote references for these authors.

II. Methods and Materials

(1) Materials

The melts were made up from calcium oxide and black magnetic rouge. The lime was Baker's "calcium oxide, lump, from marble." An analysis of one of the lumps gave SiO_2 0.20%, Fe_2O_3 1.14%, Al_2O_3 0.86%, CaO 90.67%, and MgO 1.96%. The material was not uniform in composition (lump from lump). The lumps were not pulverized until the individual charges were weighed out, so that slacking would be held at a minimum. There was some difficulty from "dusting out" of the charge materials from the crucibles when heat was applied. It will be noticed in Table II that some of the melts show the presence of magnesia and some do not. This was caused by nonuniformity in the lumps of lime.

The iron oxide used was in the form of black magnetic rouge,* which is a particularly pure form of iron oxide used for metallographic polishing. Some melts were prepared with Baker's C.P. ferric oxide, the recorded analysis of which showed a SiO_2 content of 0.14%. Previous experience has shown that these two forms of iron oxide may be used interchangeably with the same final results.

The lime was not as pure as might be desired, but it appears to be difficult to obtain calcium oxide that is free from silica in suitable form. The amounts of impurity introduced by these materials, however, do not seem to vitiate seriously the results obtained.

TABLE II

CHEMICAL ANALYSES OF SLAGS

Slag No.	Weight (%)						
	SiO_2	FeO	Fe_2O_3	CaO	MgO	Met. Fe	Total Fe
150	0.07	77.14	19.50	1.96		0.36	73.97
151	0.18	76.00	14.52	7.98		0.33	69.58
152	0.20	73.09	14.52	10.37		0.51	67.48
153	0.30	56.76	26.44	14.27	0.32	0.25	62.87
154	0.48	43.12	29.33	23.81	0.63	1.62	55.71
155	0.49	39.34	27.73	27.63	0.09	2.93	53.05
156	0.35	41.96	27.10	26.83	Tr	2.05	53.63
157	0.74	34.15	24.79	38.60		0.73	44.61
158	0.64	24.24	23.02	50.28		0.36	35.55
159	0.92	24.34	14.24	58.25	1.16	0.22	28.32

[14] E. Martin and R. Vogel, "System Iron, Iron Oxide, Calcium Orthoferrite," *Arch. Eisenhüttenw.*, **8**, 249–54 (1934–35); *Ceram. Abs.*, **14** [5] 128 (1935).

[15] E. Martin, "Ferrites of Calcium and Barium," *Chim. & Ind.* [Special No.], pp. 406–407 (May, 1924); *Jour. Soc. Chem. Ind.*, **43**, B867 (1924); *Ceram. Abs.*, **4** [1] 2 (1925).

* Obtained from Binney and Smith, New York, N. Y.

(2) Method of Melting

Melting was conducted in crucibles machined from bars of Armco iron; the inside dimensions were 31 mm. in diameter and 90 mm. deep, with a wall thickness of 5 mm. Charges of the 100-gram lime-iron oxide mixture, finely ground and thoroughly mixed, were melted in open crucibles in a gas-fired furnace with free access of the furnace gases. Highly oxidizing conditions were maintained so that heavy scaling of the crucible walls occurred.

The temperature of heating was approximately 1450°C in all cases, and heating was continued until quiet melts were obtained. The crucibles and melts were furnace-cooled, but coarse crystal structures were not obtained, as seen from the photomicrographs (Figs. 3 to 17), which are all at 1000×.

(3) Chemical Analysis

All of the slags produced in this series were readily soluble in HCl and in boiling 15% H_2SO_4. They offered no analytical difficulties. The usual methods of chemical analysis were used and call for little comment.

Iron was determined as "total iron," "ferrous iron," and "metallic iron"; "ferric iron" was obtained by difference. In regard to the determination of metallic iron, some analysts have advocated the use of the copper-sulfate method; but evidence was found which seemed to preclude the use of this method for slags of this series (see results of $CuSO_4$ etching on slag No. 156, Fig. 12). The mercuric chloride method was used.[16]

(4) Microscopic Examination

Specimens from the melts were examined by means of polished sections, thin sections, and strewn powder slides. The polished sections were found to give the most useful information, and this method of examination is recommended, especially where melts have a fine texture and where the presence of eutectics is to be detected. Owing to the opacity of the constituents and their fine crystal structure, it was difficult to produce sections thin enough to yield satisfactory photomicrographs. For this reason, the illustrations are limited to photomicrographs of polished sections.

The method of preparation of the polished sections was exactly similar to that used in metallography, described in detail by Crook and Philbrook.[17] In the case of specimens containing free excess lime, an innovation was made by substituting an alcohol emulsion of black rouge for the final polishing instead of the usual water emulsion. In this way, the corrosion of the lime crystals was prevented (slags Nos. 157, 158, and 159, Figs. 13 to 17).

In most cases, the color contrasts of the various microscopic constituents with reflected light were slight. It was necessary, therefore, to increase the contrast by using oblique illumination in producing the photomicrographs.

[16] G. E. F. Lundell, J. Hoffman, and H. A. Bright. Chemical Analysis of Iron and Steel, p. 151. John Wiley & Sons, New York, 1931.

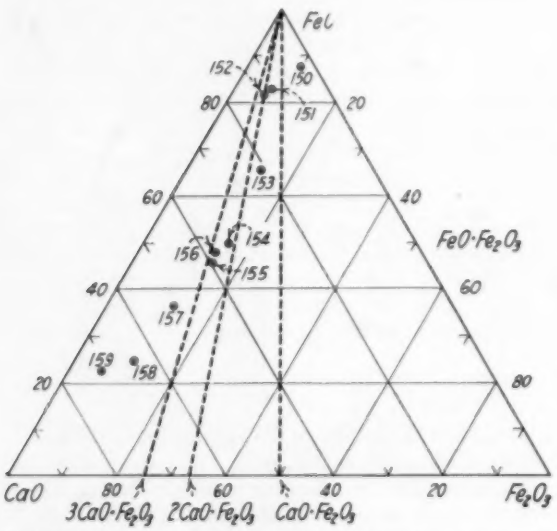

FIG. 2.—Composition diagram, iron oxides–lime (molecular per cent).

III. Description of Photomicrographs

(1) General

Differing from the series Fe_2O_3–CaO, described by Sosman and Merwin,[3] the present series consists of a ternary series essentially between Fe_2O_3–FeO–CaO. Small quantities of SiO_2, and sometimes magnesia, are present; but their amount is small and can scarcely affect the general mineralogy of the series.

The presence of large quantities of FeO in the slags is to be expected because of the strong reducing power of the metallic iron with which the slags were melted.

The general trend of "mineral" formation, as the amount of lime is increased, was found to be as follows: with small quantities of lime, *i.e.*, considerably below 10 mol. %, the slags consist of monoferrite and FeO containing Fe_2O_3 in solid solution. When 10 mol. % of CaO is present, the slag should be well over into the diferrite area (it will be shown later that it is doubtful if this compound is formed). There seems to be good evidence that the ferrite formed is $3CaO \cdot Fe_2O_3$ in all slags with the possible exception of No. 150 (Fig. 3). Slags containing up to about 40 mol. % CaO consist of $3CaO \cdot Fe_2O_3$ and FeO, and those containing between 12 and 50 mol. % CaO show the presence of a eutectic between calcium ferrite and ferrous oxide. The eutectic point appears to lie at about 38 to 40 mol. % CaO under the particular conditions of melting which apply to these slags.

The eutectic between Fe_2O_3 and $CaO \cdot Fe_2O_3$ is given by Sosman and Merwin at about 20 mol. % CaO. There is no reason to expect that the eutectic between FeO and $CaO \cdot Fe_2O_3$ should be at the same lime composition as the eutectic between $3CaO \cdot Fe_2O_3$ and FeO.

[17] W. J. Crook and W. R. Philbrook, "Black Magnetic Rouge Polishes Rapidly and Without Flow," *Metal Progress*, **21**, 72–74 (May, 1932).

Free lime does not make its appearance in the slags until a lime content of between 40 and 50 mol. % is reached. The slags which contain in excess of some amount of lime between about 40 and 50 mol. % consist of free lime, calcium ferrite, and FeO.

All of the slags in the series contain metallic iron, which is easily seen in the polished sections. Small quantities of silicate (probably $2CaO \cdot SiO_2$) are also present and may be observed in some of the sections.

(2) Detailed Description

Slag No. 150: This slag (Fig. 3) consists essentially of FeO, containing some Fe_2O_3 in solid solution and monocalcium ferrite. In the polished section, there is little to differentiate the ferrite in this slag from the ferrite in slags containing more lime except for the acicular crystal habit (compare slags Nos. 152 and 153, Figs. 5 to 7, with No. 150). No trace of eutectic

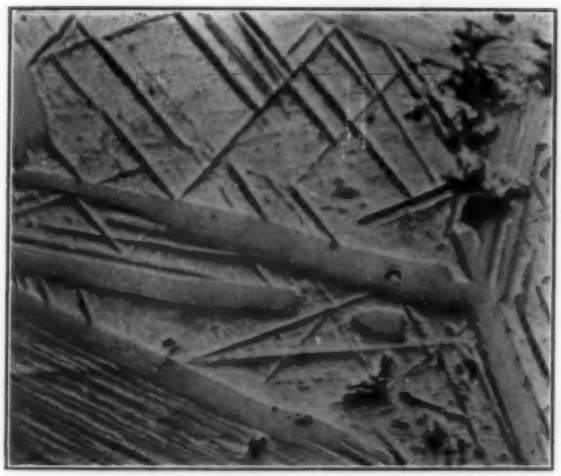

FIG. 3.—Slag No. 150, 1000×.

structure could be found in slag No. 150. It is possible that $CaO \cdot Fe_2O_3$ does not form a eutectic with FeO. The striations occurring in the FeO matrix of this slag call for some comment. At first they were thought to be polish scratches, but no amount of care in polishing was able to remove them, and they were found to persist in all cases where excess FeO was present. They are believed to be inherent in the structure itself. It has been suggested* that the striations may be caused by some transformation in the oxide or by the precipitation of some substance along the crystal planes. The presence of CaO might increase the probability of some such precipitation.

There is, however, another possible explanation. In iron-oxide melts, prepared in connection with other series (*e.g.*, iron oxides-silica in iron crucibles), the FeO produced contained a proportion of Fe_2O_3 in solid

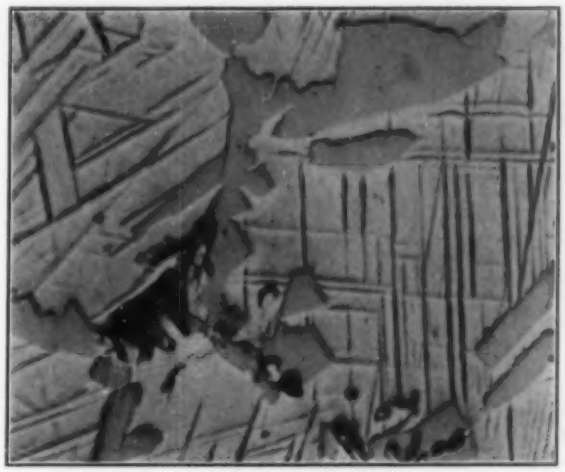

FIG. 4.—Slag No. 151, 1000×.

solution. In such melts, the striations did not appear; *e.g.*, a slag containing in molecular per cent SiO_2 0.04, FeO 92.75, and Fe_2O_3 4.58, and melted under the same conditions as in the present series (iron oxides-lime) showed no striations.

In the iron oxides–lime series, the CaO present combines with Fe_2O_3, removing this compound from solid solution with FeO. The striations may be inherent in relatively or wholly pure FeO.

Slags Nos. 151 and 152: The analyses and microstructures of these slags (Figs. 4, 5, and 6) are closely similar. Particular care was taken in polishing the specimen from slag No. 152, but all efforts failed to eliminate the striations. The slags consist of calcium ferrite in a matrix of FeO. No eutectic structure could be found in slag No. 151, but small eutectic areas were visible in slag No. 152 (not shown in field of the photomicrographs). Metallic iron is revealed as the white, high luster constituent. From their position in the composition diagram, it would be expected that these slags (as well as slag No. 152) would contain both mono- and di-calcium ferrites; but no evidence of the presence of these two ferrites could be found, even in thin sections or powder slides.

Slag No. 153: In this slag (Fig. 7), large areas of eutectic are visible, together with excess FeO. The eutectic is between triferrite and ferrous oxide (in distinction between the eutectic $CaO \cdot Fe_2O_3$ and Fe_2O_3 described by Sosman and Merwin). It will be noticed that the striations still persist in the excess FeO areas but apparently are absent in the eutectic FeO.

Slags Nos. 154 and 155: These slags (Figs. 8, 9, and 10) have a structural composition similar to No. 153 but they contain much less excess FeO because they are but slightly on the excess FeO side of the eutectic. The presence of metallic iron is particularly prominent in slag No. 155, which contains the largest percentage (4.11 mol. %) of any of the slags studied in this series. The metallic iron is intimately connected with the crystallization of the FeO. In many cases, the crystals merge into each other.

* Private correspondence of B. A. Rogers, U. S. Bureau of Mines.

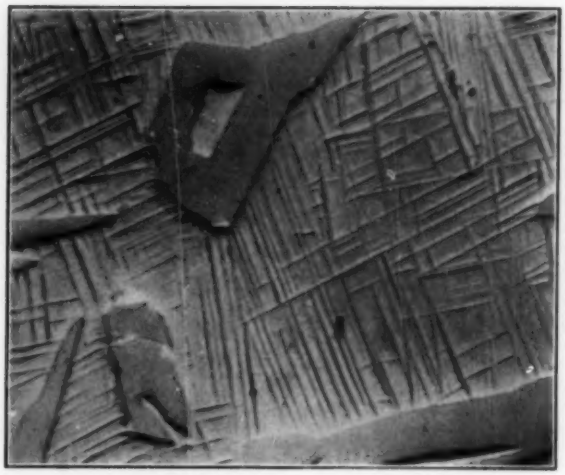

FIG. 5.—Slag No. 152, 1000×.

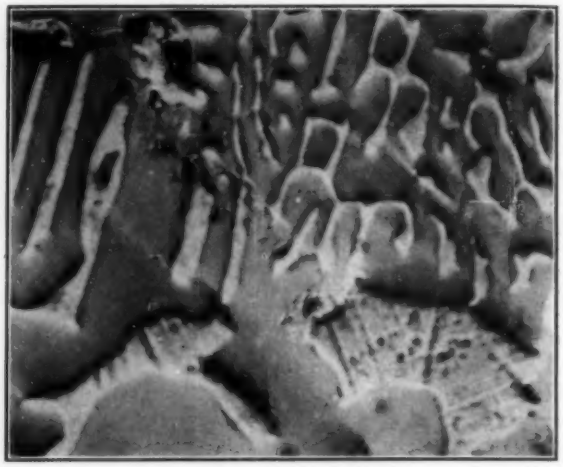

FIG. 8.—Slag No. 154, 1000×.

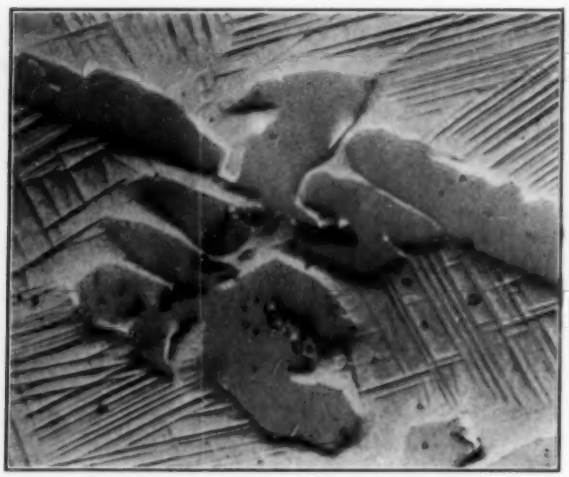

FIG. 6.—Slag No. 152, 1000×.

FIG. 9.—Slag No. 154, 1000×.

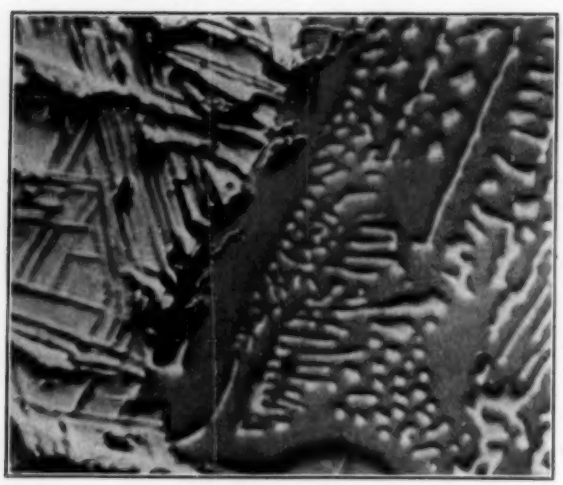

FIG. 7.—Slag No. 153, 1000×.

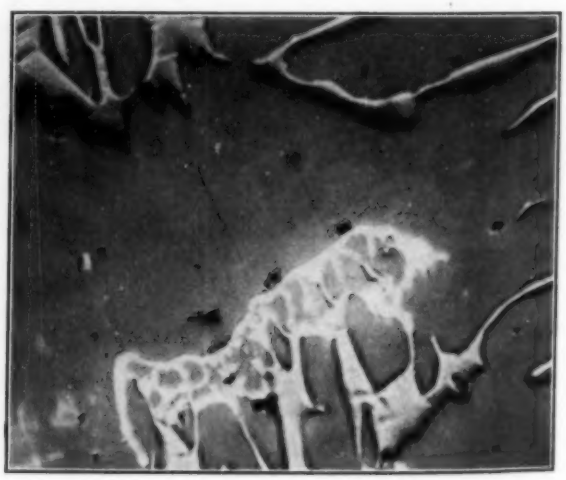

FIG. 10.—Slag No. 155, 1000×.

Slag No. 156: This slag (Figs. 11 and 12) is very close to the eutectic composition, but it is probably slightly on the excess ferrite side. The eutectic probably lies between slags Nos. 155 and 156. These slags have closely the same analysis. In slag No. 156, a check was made on the identity of that structure which has been described as metallic iron. To this end, the specimen was etched for 10 seconds in 5% aqueous neutral solution of copper sulfate. The results of this etching are shown in Fig. 12. It was found that metallic copper was precipitated with equal facility on the FeO and on the metallic iron. Previous experience (slag No. 32, iron oxides-silica series) showed that, with a slag containing SiO_2 0.78, FeO 91.69, Fe_2O_3 5.20 (in molecular per cent) and metallic iron 2.32 and in which the Fe_2O_3 occurred as solid solution in the FeO, a similar copper sulfate etch resulted in a ready precipitation of copper on the metallic iron but only a slight precipitation on the FeO–Fe_2O_3 solid solution. Tests on natural magnetite and hematite gave no precipitation of copper.

In the case of slag No. 156, it seems that sufficient lime is present to unite with almost all the Fe_2O_3 so that the FeO may occur in a relatively pure form. The possibility exists that while FeO, containing quantities of Fe_2O_3 in solid solution, will not precipitate copper from copper sulfate solution, pure FeO will do so as readily as does metallic iron. The ferrite, it will be noticed, is unattacked by copper-sulfate solution.

Slags Nos. 157, 158, and 159: The general appearance of the structures of these slags (Figs. 13 to 17) differs from those previously described because of the appearance of free excess lime. This shows as dark-colored areas in the photomicrographs. These slags lie to the left of the line representing $3CaO \cdot Fe_2O_3$ in the composition diagram. The fact that these slags contain free lime and that slags Nos. 154, 155, and 156 do not would seem to offer strong evidence that the ferrite formed in this series has the composition $3CaO \cdot Fe_2O_3$ and that, under conditions of melting in the presence of metallic iron, the diferrite is not formed.

Referring again to the slags Nos. 157, 158, and 159 (Figs. 13 to 17), it may be noticed that the dark areas of lime are not homogeneous but contain elongated particles which seem to consist of tricalcium ferrite. Identification of these particles is difficult on account of their small size. In addition to the dark lime areas, certain other still darker areas (structureless) may be observed. These are of silicate, resulting from uniting the SiO_2 impurity with lime to form $2CaO \cdot SiO_2$. The matrix of the slags is $3CaO \cdot Fe_2O_3$ containing FeO and metallic iron in addition to free CaO. The FeO shows a slightly lighter color than the ferrite.

IV. Occurrence of Metallic Iron

Metallic iron was found in all of the slags of this series. The highest proportions were found in the slags which lay close to the eutectic composition.

Chaudron[18] and Eastman[19] found that ferrous oxide prepared at high temperature becomes unstable on cooling and partly decomposes; *e.g.*, $4FeO = Fe_3O_4 + Fe$. This equation might be written $3FeO = Fe_2O_3 + Fe$, inasmuch as Fe_3O_4 may be written as $FeO \cdot Fe_2O_3$. Previous experimentation by the writer has shown that unstability on cooling is not necessarily the cause of the production of metallic iron, *e.g.*, the presence of metallic iron, melting in iron crucibles, is a controlling factor. Iron oxide, melted in silica crucibles, did not contain metallic iron, which is produced in iron-oxide melts made in platinum. Consideration, however, should be given to the fact that silica-crucible melts result in slags consisting essentially of $FeO \cdot Fe_2O_3$. The melts produced in iron crucibles contained large amounts of excess FeO and little or no magnetite, as they did in the present iron oxide-lime series. The decomposition theory, therefore, may be the true one. This, however, does not explain the fact that, although the slags show a steady decrease in the amount of free FeO in the present series, as lime is increased the metallic iron shows a fairly sharp peak in the slags whose compositions fall close to the eutectic composition (between FeO and $3CaO \cdot Fe_2O_3$). It does seem to indicate, however, that lime does not have a tendency to promote any such reaction as $3FeO + 2CaO = 2CaO \cdot Fe_2O_3 + Fe$.

V. Thin Sections and Powder Slides

All of the constituents appearing in the slags, except free lime, possess a high degree of opacity. Even with the thinnest of thin sections, it is difficult to secure photomicrographs. Slag No. 150 (Fig. 3) appeared to be entirely opaque; even the smallest of particles in a powder slide appeared black with transmitted light. In all of the other slags, the ferrite (in thin sections) appeared to be identical in color, deep red, but when viewed in powder slides, this ferrite was found to vary in color, depending on the thickness of the particle. Larger particles were red but passed through brownish-yellow to a light yellow in very small particles. With the exception of slag No. 150, the ferrite had exactly the same appearance in all the slags, irrespective of their CaO content or their position on the composition diagram. No free lime could be detected until slag No. 157 was reached. The examination by transmitted light confirmed the observations made with reflected light.

Sosman and Merwin[3] state that calcium monoferrite, $CaO \cdot Fe_2O_3$, forms black crystals, which by transmitted light have a deep red color like hematite. Winchell[20] states "color black in mass and deep red in powder, like hematite." Sosman and Merwin state that dicalcium ferrite, $2CaO \cdot Fe_2O_3$, crystallized well, giving black crystals which are yellowish-brown by transmitted light. Winchell gives for this compound

[18] G. Chaudron, "Réactions Réversibles de l'Oxyde de Carbone sur les Oxydes de Fer," *Compt. Rend.*, **172,** 152 (Jan.–June, 1921).

[19] E. D. Eastman, "Equilibria in the System Iron–Oxygen and Iron–Hydrogen–Oxygen," *Jour. Amer. Chem. Soc.*, **44,** 975–98 (1922).

[20] A. N. Winchell, Microscopic Characters of Artificial Inorganic Solid Substances or Artificial Minerals, 2d ed. John Wiley & Sons, Inc., New York, 1931; *Ceram. Abs.*, **11** [5] 323 (1932).

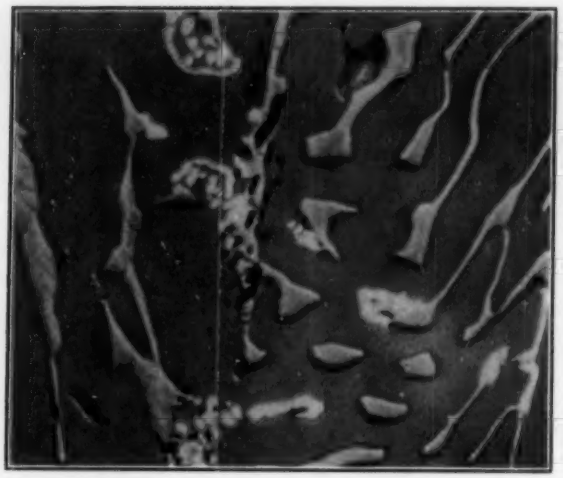

FIG. 11.—Slag No. 156, 1000× (unetched).

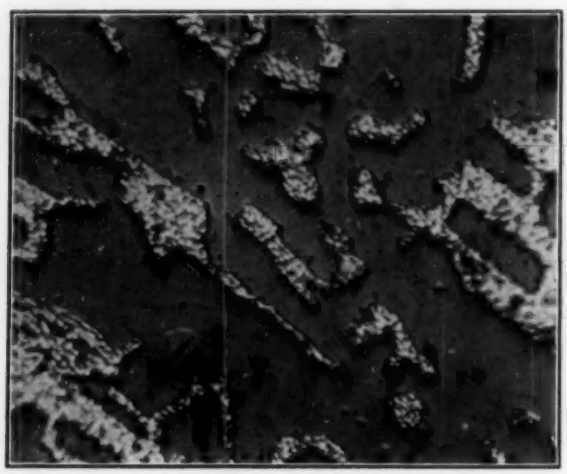

FIG. 12.—Slag No. 156, 1000× (etched with 5% $CuSO_4$).

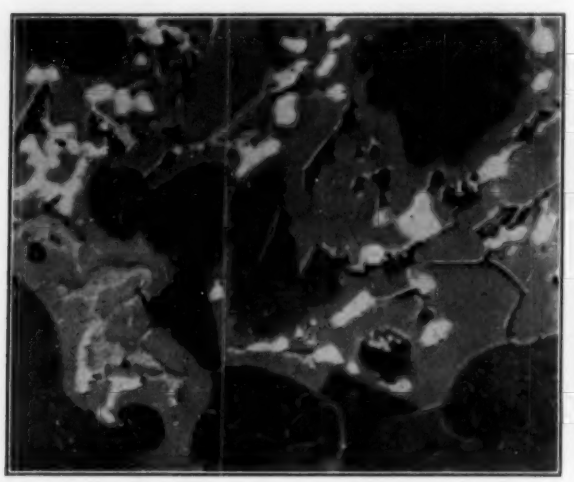

FIG. 13.—Slag No. 157, 1000×.

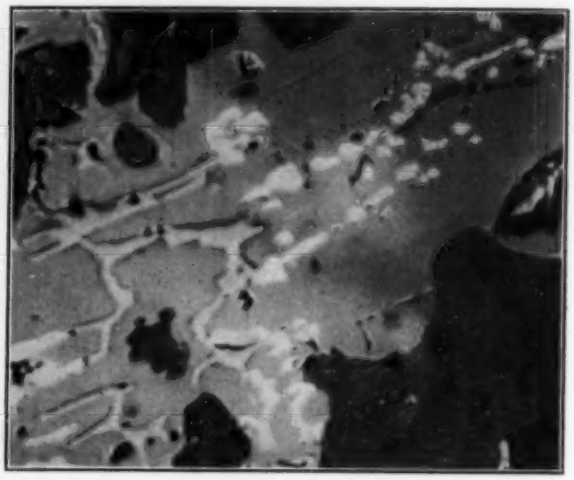

FIG. 14.—Slag No. 157, 1000×.

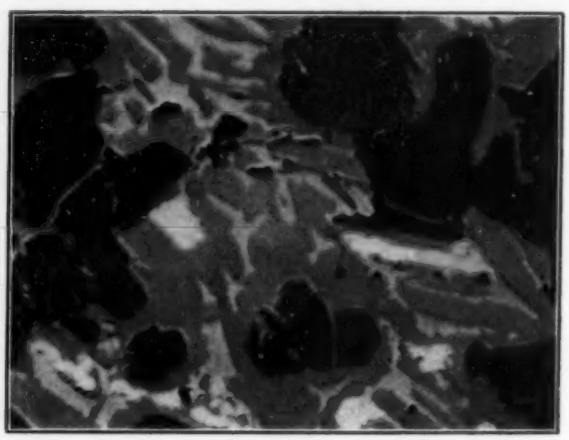

FIG. 15.—Slag No. 158, 1000×.

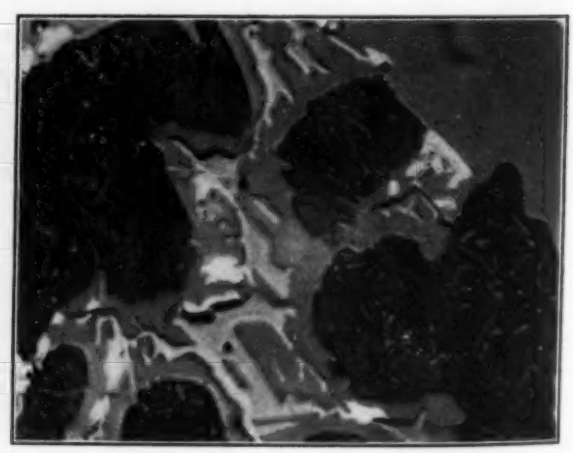

FIG. 16.—Slag No. 158, 1000×.

"color black; yellowish-brown in section."

The ferrite found in this series (except that in slag No. 150) was distinctly deep red, even in a *thin* thin section. In powder slides, the very small particles showed a brownish-yellow to yellow color; larger particles were red.

VI. Results of Chemical Analyses

The results of chemical analyses of the slags are shown, in weight per cent, in Table II; in Table III, the results are given in molecular percentages.

TABLE III

CHEMICAL ANALYSES OF SLAGS*

Slag No.	Molecular %				
	SiO_2	FeO	Fe_2O_3	CaO	Met. Fe
150	0.09	86.71	9.86	2.83	0.51
151	0.23	81.37	6.99	10.96	0.45
152	0.23	80.35	6.19	12.64	0.61
153	0.40	64.36	13.48	21.40	0.36
154	0.64	47.68	14.59	34.79	2.30
155	0.63	42.89	13.59	38.78	4.11
156	0.46	45.81	13.31	37.54	2.88
157	0.92	35.34	11.55	51.22	0.97
158	0.76	24.17	10.32	64.29	0.46
159	1.02	21.64	5.94	71.14	0.26

* In calculating this table, magnesia in mol. % was added to the lime.

Referring to these tables, it may be seen that with increase in lime the amount of ferric oxide does not follow a steady course. The analysis of slag No. 153 appears to be somewhat out of line. If this slag is eliminated, the remainder may be divided into three groups, each having three members: (*a*) Nos. 150, 151, and 152; (*b*) Nos. 154, 155, and 156; and (*c*) Nos. 157, 158, and 159. In group (*a*), as lime is increased from 2.8 to 12.6 mol. %, the Fe_2O_3 gradually decreases from 9.8 to 6.2 mol. %. This group lies in the mono- and di-ferrite areas of the composition diagram. Group (*b*), however, lies in the di- and tri-ferrite areas, and the Fe_2O_3 content of the group increases to 13 or 14 mol. %, the highest in the series. The slags of this group are composed largely of eutectic (FeO–$3CaO \cdot Fe_2O_3$). Group (*c*) lies in the excess lime area (excess over $3CaO \cdot Fe_2O_3$) and shows a gradual decrease in Fe_2O_3 with increase in lime. In this group, the decrease in Fe_2O_3 may be due, at least in part, to dilution. It may also be noticed that those slags containing the largest proportion of Fe_2O_3 also contain the most metallic iron.

No explanation is offered for this phenomenon. The number of analyses is probably insufficient to justify any conclusions.

In Table IV, the analyses have been recalculated to form a ternary system. The silica and metallic iron were calculated out of the molecular analyses. Following the findings of Négresco and Crook,[21] the silica in slag No. 150 was united with FeO and CaO to form $2CaO \cdot FeO \cdot 2SiO_2$; and in the remainder of the slags, the silica was united with lime to form $2CaO \cdot SiO_2$.

TABLE IV

RECALCULATED ANALYSES

Slag No.	Molecular %		
	FeO	Fe_2O_3	CaO
150	87.30	9.93	2.77
151	82.30	7.08	10.62
152	81.39	6.27	12.34
153	65.38	13.70	20.92
154	49.77	15.26	34.97
155	45.63	14.45	39.92
156	47.85	13.91	38.24
157	36.71	12.00	51.29
158	24.85	10.60	64.55
159	22.39	6.14	71.47

The calculated results, Table IV, have been plotted in the triangular composition diagram (Fig. 2, p. 316). Referring to this diagram, it is seen that slag No. 150 should contain monoferrite and (considering the relative proportions of CaO and Fe_2O_3 in this slag) the assumption of the formation of monoferrite is justified. Microscopic examination shows that the ferrite formed in this slag is different from that formed in all the others of the series.

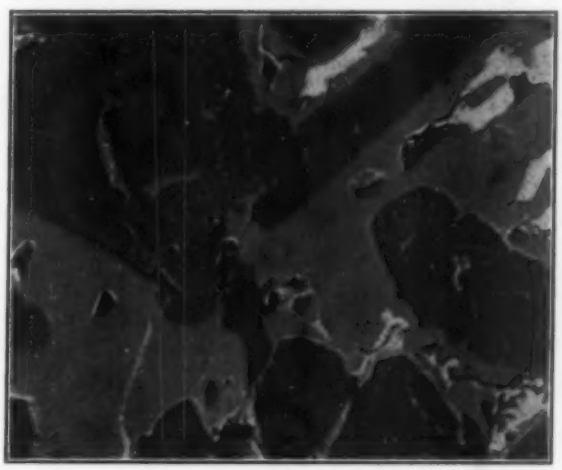

FIG. 17.—Slag No. 159, 1000×.

The most important fact brought out by Fig. 2 is that slags Nos. 154, 155, and 156, which do not contain free excess lime, lie in the $2CaO \cdot Fe_2O_3$–$3CaO \cdot Fe_2O_3$ area. The fact that free lime does appear in slag No.

[21] T. Négresco and W. J. Crook, "Constitution du Système SiO_2–FeO–Fe_2O_3–CaO (+MgO)," *Bull. sect. sci. acad. roumaine*, **18** [3–5] 67–73(1936); *Ceram. Abs.*, **16** [7] 222 (1937).

157, whose plotted position lies to the left of the line joining the points "$3CaO \cdot Fe_2O_3$" and "FeO" in the diagram, would appear to be competent evidence that the ferrite formed in all the slags (except No. 150) was the triferrite, $3CaO \cdot Fe_2O_3$, if the results of microscopic observation are taken into account.

VII. Summary and Conclusions

(1) The usually accepted constitutional diagram for the series iron oxides–lime is that of Sosman and Merwin (Fig. 1). This binary diagram, as published, is concerned with the compounds and eutectic formed between CaO and Fe_2O_3.

In this system it has been shown by Sosman and Merwin that two ferrites are formed, $CaO \cdot Fe_2O_3$ and $2CaO \cdot Fe_2O_3$, with a eutectic, between $CaO \cdot Fe_2O_3$ and Fe_2O_3, containing about 25 mol. % CaO.

(2) The literature shows a considerable divergence of opinion regarding the basicity of the ferrite formed. In general, those authors who based their observations upon steelmaking slags expressed the opinion that the triferrite is formed, while those working with melts produced without contact with metallic iron, found only $CaO \cdot Fe_2O_3$ and $2CaO \cdot Fe_2O_3$.

(3) In the present work, evidence was found which indicates that when mixtures of iron oxide and lime are melted (under oxidizing conditions) in contact with metallic iron, a ternary system between CaO–FeO–Fe_2O_3 prevails and that the compound formed between lime and ferric oxide has the composition $3CaO \cdot Fe_2O_3$, with the possible exception of melts containing somewhat less than 10 mol. % CaO.

(4) A eutectic was found between FeO and $3CaO \cdot Fe_2O_3$, which contains approximately 40 mol. % CaO.

(5) It is believed that when the "mineralogy" of basic steelmaking slags is being considered the ternary system CaO–FeO–Fe_2O_3 should be substituted for the binary system CaO–Fe_2O_3, which has been generally used in the past.

Department of Mining Engineering
Stanford University
Stanford University, California

THE SERIES IRON OXIDES–SILICA*

By Welton J. Crook

Abstract

A review is presented of the previous work by the writer on the general series FeO–Fe_2O_3–SiO_2–CaO (MgO) as related to steelmaking slags, in which 12 quasi-quaternary mineral systems are formed. A "plane of partition" of the iron oxides (FeO and Fe_2O_3) is also shown to exist. A method is explained by which, having a partial analysis of a slag, the position of the slag in the representative tetrahedron may be found and the series of minerals formed may be determined.

The present paper is a study of the system iron oxides–silica under conditions of formation with and without the presence of metallic iron. In the former case, two distinct eutectiferous series are formed, *viz.*, (*a*) wüstite-fayalite and (*b*) fayalite-tridymite. The reducing power of metallic iron is so great that substantially the same proportions of FeO and Fe_2O_3 are obtained when melting is conducted either under strongly oxidizing conditions or in a neutral atmosphere. A "eutectoid" between magnetite and tridymite contains equal molecular proportions of SiO_2 and Fe_3O_4. When iron oxide and silica are heated at 1600°C or higher in siliceous crucibles, the resulting melts consist essentially of tridymite and magnetite, forming an entirely different series than that obtained by melting in the presence of metallic iron. In connection with both series of melts, ferric oxide exhibits a much greater affinity for ferrous oxide than for silica.

I. Introduction

The oxides of iron play an important rôle in any discussion of the slags used in steelmaking processes. This fact has received considerable technical recognition during the past few years, especially in connection with the efforts which have been made to control to some extent the content of ferrous oxide in steel by regulating slag conditions in the furnace rather than to rely entirely upon deoxidizing alloys and reagents added in the ladle.

The effect of ferrous oxide on the properties of steel is well known and its effect in steels of lower carbon content, especially those which are to be subjected to heat treatment or case hardening or those to be used in

* Presented at the Golden Gate General Meeting, American Ceramic Society, San Francisco Calif., August 6–12, 1939. Received February 1, 1939.

steel castings, has been the subject of much study.[1]

Herty[1(a)] made actual furnace tests, devoting but little consideration to the mineralogical composition of the slags. The methods of "slag control" which originated from Herty's work do not seem to constitute a complete answer to the problem, and a much more complete understanding of slag "mineralogy" is necessary before much further advance can be made.

In order to test the validity of some of the claims in the series of United States patents granted to Greene,[2] a study was made of the quaternary system, FeO–Fe_2O_3–$CaO(MgO)$–SiO_2, by Crook[3] in which an attempt was made to lay a foundation for the study of the "mineralogy" of steelmaking slags; a series of articles also relating to certain phases of this work has been published by Négresco and Crook.[4] The generosity and interest of Research Corporation have enabled a further program of study to be undertaken at Stanford University. In laying out this program, a detailed check-up was made on the results previously obtained, and several regions were explored in the quaternary diagram in which few samples had been investigated.

II. The System Iron Oxides–Silica

To produce experimental melts in which the iron oxide present was in the ferrous state to the highest possible degree, earlier investigators have resorted to the use of iron crucibles and to melting either *in vacua* or in neutral atmospheres, such as nitrogen. Even with these precautions, however, the melts obtained were by no means free from ferric oxide. The work of Bowen and Schairer[5] on the system FeO–SiO_2 is outstanding.

The work done in Roumania was based on the use of nonmetallic crucibles, magnesite being used almost entirely. On this account, certain slag compositions, particularly those high in silica and in iron oxide, could not be made.

In investigating the series iron oxides–silica, two separate conditions must be considered, *viz.*, the compositions and "mineralogy" (1) of slags melted in the presence of metallic iron and (2) of slags melted in nonferrous (siliceous) crucibles. The results obtained under these two conditions are entirely different. Previous studies by the writer, as well as by those which are now considered, are based upon melting with free access of air.

III. Materials

(1) Iron Oxide

It is of little importance which oxide of iron is used in preparing the melts. Either magnetite or ferric oxide are suitable. When the black oxide is used in experimental melts, the starting point is really Fe_2O_3, not Fe_3O_4.

In cases where iron-oxide melts were needed without the presence of silica, the black rouge was previously purified by dissolving in HCl and filtering off any insoluble residue. The filtered solution was evaporated to dryness, thoroughly baked, and heated for two hours in Pyrex-brand beakers at just below a red heat. At this point, the material was found to contain 0.06% SiO_2, determined in a 30-gram sample. The residue was dissolved again in HCl, refiltered, and baked for two hours. At this point, a slight acid odor could still be detected. The baked residues were detached from the beakers and roasted, with stirring, in a platinum dish at a dull red heat. Copious yellowish-brown fumes were evolved. Roasting was continued until no acid fumes could be detected. Before roasting, the material had a reddish-brown hematite color. After roasting, the material was black but entirely nonmagnetic. It roasted to a fine state of subdivision with general characteristics similar to the original powder.

In cases where melts were made which included silica, either Baker's ferric oxide or unpurified black rouge was used.

(2) Silica

The silica used was ordinary floured quartz such as is used in fire assay charges. Spectrographic examination showed only slight traces of iron, lime, and magnesia.

(3) Crucibles

The iron crucibles were machined from Armco iron-bar stock; they were 4 inches long, $1^9/_{16}$ inches outside diameter, and the walls were $^3/_{16}$ inch thick. The siliceous crucibles were Battersea triangular-topped,

---

[1] (*a*) C. H. Herty, *et al.*, "Physical Chemistry of Steel Making." Mining and Metallurgical Advisory Boards, Pittsburgh, 1934.

(*b*) W. J. Crook, "Heat Treatment of Low Carbon Steel," *Metal Progress*, **28** [4] 47–52 (Oct., 1930).

(*c*) H. W. McQuaid and E. W. Ehn, "Effect of Quality of Steel on Case-Carburizing Results," *Trans. Amer. Inst. Mining Met. Engrs.*, **67**, 341–91 (1922).

(*d*) H. S. Taylor, "Comparison Between McQuaid-Ehn Carburizing Test and Regeneration Test." Thesis in partial fulfillment of the requirements for the degree of Metallurgical Engineer, Stanford University, 1932.

[2] A. E. Greene, "Treatment of Iron and Steel in the Electric Furnace," U. S. Pat., 1,502,052, March, 1935.

[3] W. J. Crook, "Recherches Expérimentales sur la Constitution Minéralogique et sur l'Action Chemique des Scories de l'Élaboration de l'Acier." Thesis, École Polytechnique "Roi Carol II," Bucharest, 1936, for the degree of Doctor-Engineer.

[4] (*a*) W. J. Crook, "Sur l'État à Oxydation du Fer dans Certaines Scories de l'Élaboration de l'Acier," *Bull. Math. Phys. École Polytech., Bucarest*, **7** [19] 73–84 (1936).

(*b*) T. Négresco and W. J. Crook, "Sur les Relations d'Équilibre des Oxydes du Fer, dans les Scories des Fours d'Affinage," *Compt. Rend.* **202**, 2154–57 (1936).

(*c*) T. Négresco and W. J. Crook, "Constitution du Système SiO_2 + FeO + Fe_2O_3 + $CaO(MgO)$," *Bull. sect. sci. acad. roumaine*, **18**, 67–73 (1936).

(*d*) T. Négresco and W. J. Crook, "Sur les Rapports Éxistant entre la Composition des Scories et Leur Rôle dans l'Élaboration de l'Acier," *ibid.*, **18**, 74–80 (1936).

[5] N. L. Bowen and J. F. Schairer, "System FeO–SiO_2," *Amer. Jour. Sci.* [5th Ser.], **24**, 177–213 (1932); p. 200.

TABLE I

SERIES FeO–Fe_2O_3–SiO_2

ANALYSIS AND COMPOSITION OF EXPERIMENTAL MELTS*

	Slag No. 102	32	33	34	103	100	104	105	101	106	109	108	110	111	112
						Analysis (wt. %)									
SiO_2	0.04	0.62	2.54	3.71	9.70	22.96	32.28	32.76	35.48	46.06	47.30	0.22	0.18	2.96	8.61
FeO	88.01	86.12	84.65	84.11	80.51	71.49	63.81	62.86	60.89	50.85	46.71	45.61	12.63	25.94	24.90
Fe_2O_3	9.66	10.88	10.16	11.40	8.82	4.28	1.89	2.38	2.36	1.96	5.62	53.94	86.09	69.38	62.05
Met. Fe	1.94	1.71	1.65	0.66	0.62	0.13	0.22	0.20	0.24	0.17					
Total Fe	77.11	76.26	74.56	74.01	69.37	58.69	51.15	50.66	49.22	41.05	40.62	73.10	70.03	68.69	62.75
						Analysis (mol. %)									
SiO_2	0.04	0.78	3.22	4.69	11.96	27.19	37.30	37.91	40.55	51.49	53.48	0.37	0.42	5.83	16.35
FeO	92.75	91.69	89.68	88.99	83.00	70.74	61.61	60.80	58.15	47.50	44.13	65.03	24.49	42.74	39.44
Fe_2O_3	4.58	5.20	4.84	5.42	4.22	1.91	0.82	1.04	1.00	0.82	2.39	34.60	75.09	51.43	44.21
Met. Fe	2.63	2.32	2.26	0.91	0.82	0.16	0.27	0.25	0.29	0.19					
						Minerals (mol. %)									
Wüstite	97.34	96.85	94.14	93.84	83.20	40.05									
Fayalite	0.04	0.79	3.44	5.16	15.72	59.60	79.20	76.23	68.30	44.45	37.35				
Met. Fe	2.62	2.36	2.42	1.00	1.08	0.35	0.70	0.64	0.69	0.37		Sinter	Sinter	Sinter	
Tridymite							17.97	20.48	28.62	53.62	58.37				29.31
Magnetite							2.13	2.65	2.39	1.56	4.28				70.69
						Structural (mol. %)									
Wüstite	97.31	96.29	91.72	90.21	73.14										
Wüstite-fayalite eutectic	0.07	1.35	5.86	8.79	25.78	96.96									
Met. Fe	2.62	2.36	2.42	1.00	1.08	0.35	0.70	0.64	0.69	0.37					
Fayalite						2.69	39.09	30.52	4.42						
Fayalite-tridymite eutectic							58.08	66.19	92.50	64.36	54.08				
Tridymite										33.71	41.64				29.31
Magnetite							2.13	2.65	2.39	1.56	4.28				70.69

* Iron crucibles were used for slags Nos. 102 through 106; siliceous crucibles for slags Nos. 109 through 112.

tapered crucibles, 3¼ inches long, with a capacity of 80 milliliters.

The melting furnace was gas-fired, using a centrifugal air-gas mixer. By bleeding in a small quantity of oxygen to the mixer, temperatures of 1600°C were easily reached in a few minutes.

The charges were compounded by mixing the components thoroughly in a porcelain mortar before placing in the crucibles. No crucible covers were used. The melting was conducted with free access of the furnace atmosphere.

IV. Analytical Methods

The general analytical methods used have been described in detail in previous publications.[4] Some of the slags, especially those melted in iron crucibles, contained metallic iron. This was determined by the mercuric-chloride method given by Lundell, Hoffman, and Bright.[6] FeO was determined by a modified method described by Crook and Cunningham.[6(b)]

(1) Microscopic Examination

Specimens of the various slag melts were examined by means of polished sections, using a large Zeiss metallograph; where transparent minerals were present, the petrographic microscope was used with thin sections. In some cases, strewn powder slides were employed.

(2) Analytical Results

The analysis and structural composition of the experimental melts made both in iron and siliceous crucibles are shown in Table I. This table also shows the calculated molecular percentages of the minerals present as well as the structural composition of the slags.

---

[6] (*a*) G. E. F. Lundell, J. I. Hoffman, and H. A. Bright, Chemical Analysis of Iron and Steel, p. 151. John Wiley & Sons, New York, 1931.

(*b*) W. J. Crook and J. R. Cunningham, "Modified Method for the Determination of Ferrous Oxide," *Chemist-Analyst*, **28** [1] 4–8 (Jan., 1934).

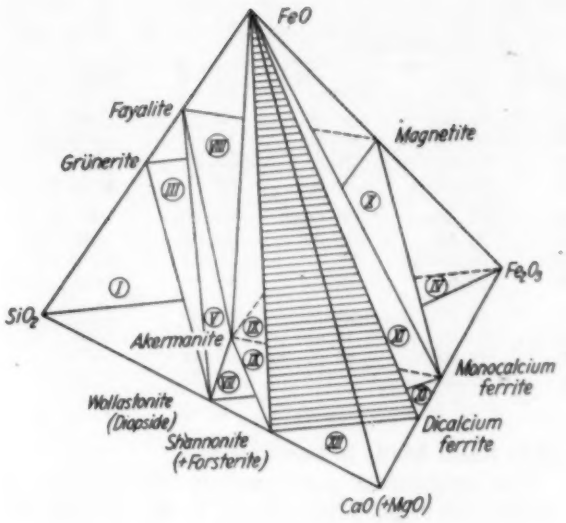

FIG. 1.—Constitutional diagram of the system SiO_2–FeO–Fe_2O_3–CaO (molecules) (T. Négresco and W. J. Crook).[4] The components of the various "mineral" areas are shown under Fig. 3.

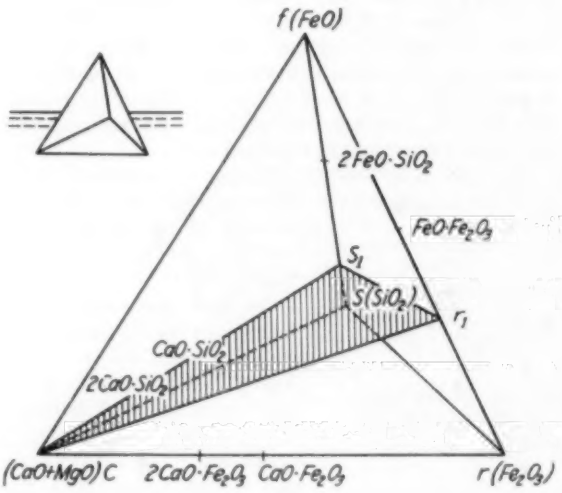

FIG. 2.—Position of plane of equilibrium of oxides of iron in the diagram of the system SiO_2–FeO–Fe_2O_3–CaO (mol. %).[4]

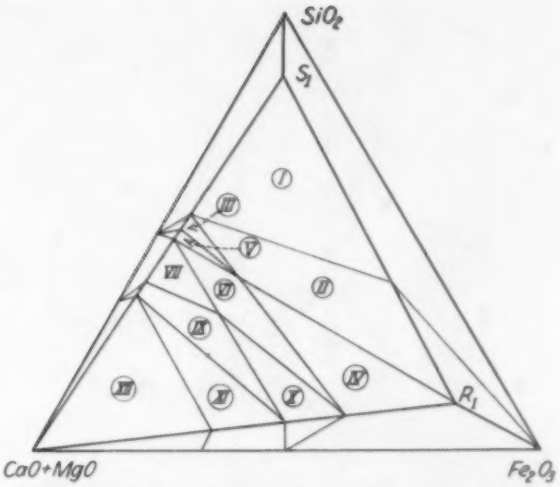

Fig. 3.—Constitutional diagram of refining slags in the presence of oxygen (mol. %) (from T. Négresco and W. J. Crook).[4] (I) silica, ferric oxide, and pyroxene; (II) ferric oxide, pyroxene, and magnetite; (III) pyroxene, magnetite, and fayalite; (IV) ferric oxide, diopside, magnetite, and monoferrite; (V) diopside, magnetite, akermanite, and fayalite; (VI) diopside, magnetite, akermanite and monoferrite; (VII) diopside, akermanite, monoferrite, and shannonite; (IX) akermanite, magnetite, monoferrite, and ferrous oxide; (X) akermanite, shannonite, monoferrite, and ferrous oxide; (XI) shannonite, monoferrite, diferrite, and ferrous oxide; (XII) shannonite, diferrite, ferrous oxide, and lime.

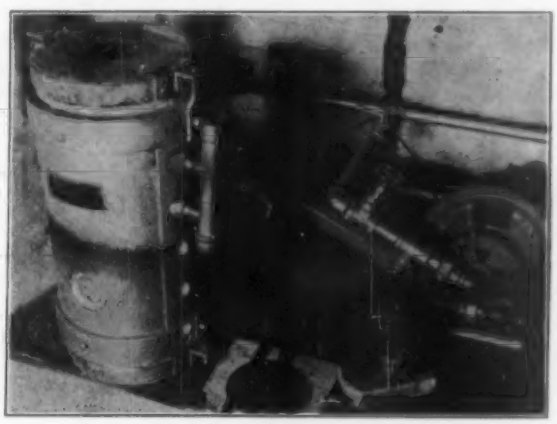

FIG. 4.—Furnace equipment.

(3) Calculation of Mineral Composition

The calculation of the mineral and structural composition of the various melts was based upon (1) the chemical analysis, (2) the microscopic observation of polished and thin sections, and (3) a study of the constitutional diagram of the series FeO–SiO_2 presented by Bowen and Schairer.[5]

It is a matter of convenience when making calculations of mineral content to deal in terms of molecules per cent, and the data of Bowen and Schairer[5] have been recalculated on this basis in Table II. This table also shows the calculated ratios of wüstite (solid solution of FeO and Fe_2O_3) to silica.

From the data in Table II, the constitutional diagram for the series wüstite–silica has been drawn and is shown in Fig. 6.

(4) Methods of "Mineral" Calculation

The system may be considered to consist of a combination of two eutectiferous series, *viz.*, (*a*) between

TABLE II

WÜSTITE AS SOLID SOLUTION OF FeO AND Fe_2O_3

Weight (%)			Mol. (%)			Mol. (%)		Temp.
FeO	Fe_2O_3	SiO_2	FeO	Fe_2O_3	SiO_2	Wüstite	Silica	(°C)
88.44	11.56	0.00	94.48	5.52	0.00	100.00	0.00	1380
82.73	9.00	8.27	84.66	4.16	10.18	90.82	10.18	1315
75.19	4.73	20.08	74.25	2.06	23.69	76.31	23.69	1215
71.53	3.32	25.15	69.39	1.44	29.17	70.83	29.17	1193
70.21	2.50	27.29	67.57	1.08	31.35	68.65	31.35	1202
68.36	2.25	29.39	65.39	0.97	33.64	66.36	33.64	1205
66.36	2.21	31.43	63.22	0.95	35.83	64.17	35.83	1203
62.65	1.39	35.96	58.93	0.59	40.48	59.52	40.48	1187
60.22	1.32	38.46	56.36	0.57	43.07	56.93	43.07	1260
58.98	1.31	39.71	55.08	0.55	44.37	55.63	44.37	1365
56.53	1.15	42.29	52.53	0.49	46.98	53.02	46.98	1475
55.37	1.14	43.49	51.31	0.47	48.22	51.78	48.22	1515

wüstite and fayalite with a eutectic at 73 mol. % wüstite and 27 mol. % silica, and (*b*) between fayalite and tridymite with a eutectic at 58 mol. % wüstite and 42 mol. % silica.

The methods of calculation are illustrated by two examples. First, taking slag No. 33, the chemical analysis in molecules per cent is SiO_2 3.22, FeO 89.68, Fe_2O_3 4.84, and metallic iron 2.26. Figure 6 shows that the minerals present in the slag are wüstite and fayalite (and metallic iron). The presence and identification of metallic iron in the melts will be discussed later. Fayalite ($2FeO \cdot SiO_2$) contains 2 mol. FeO to 1 mol. SiO_2.

This slag falls in the eutectiferous partial system, wüstite-fayalite, having a eutectic at 73 mol. wüstite and 27 mol. SiO_2, and its composition lies to the left of the eutectic so that it will consist structurally of the fayalite-wüstite eutectic plus excess wüstite (plus metallic iron). It may be calculated that 1 mol. of fayalite unites with 0.7035 mol. wüstite (FeO) to form the eutectic; conversely, 1.421 mol. fayalite unites with 1 mol. wüstite to form the eutectic. Therefore, 3.44 mol. fayalite unites with 2.42 mol. wüstite to form 5.86 mol. eutectic, leaving 91.72 mol. excess wüstite and 2.42 mol. metallic iron.

3.22 SiO_2 + 89.68 FeO + 4.84 Fe_2O_3 + 2.26 met. Fe
3.22 + 6.66 FeO
= 3.22 mol. fayalite.

83.02 FeO + 4.84 Fe_2O_3 + 2.26 met. Fe
4.84 FeO 4.84 Fe_2O_3

87.86 wüstite = 87.86 mol. wüstite.

2.26 met. Fe = 2.26 mol. met. Fe.

	Mol. (%)	
Fayalite	3.22	3.44
Wüstite	87.86	94.14
Met. Fe	2.26	2.42
	93.34	100.00

V. Discussion of Series SiO_2–FeO–Fe_2O_3

Any discussion of this series must be made under two headings, *viz.*, (1) the condition of melting in iron crucibles and (2) melting in siliceous crucibles.

(1) Melts Made in Iron Crucibles

The experimental melts made in iron crucibles are represented by slags Nos. 102, 32, 33, 34, 103, 100, 104, 105, 101, and 106. The analyses of these slags, together with their calculated molecule percentages of constituent minerals, are shown in Table I. All slags were melted with free access of the furnace atmosphere.

Slag No. 102: This slag was prepared by melting purified iron oxide in an Armco iron crucible. Examination of the polished section, without etching, revealed the presence of iron oxide (wüstite), rounded areas of a high metallic luster constituent, and occasional small areas of fayalite associated with this. The fayalite, in common with other silicates, appears as a dark constituent in reflected light.

Slag No. 32: The 0.62% silica is reflected in the presence of considerably more fayalite surrounding the particles of metallic iron than was observed in slag No. 102 (0.04% SiO_2).

The high luster constituent was found to be much less subject to attack by a 2% alcoholic solution of iodine than was a polished specimen of Armco iron under the same conditions. The scratch hardness of the constituent was also much greater when tested with the microcharacter.

By crushing in an agate mortar and subsequent screening through an 80-mesh sieve, numerous flattened particles were obtained which were strongly magnetic; under the microscope, these were found to be the only magnetic constituents of the slag and they were closely associated with particles of fayalite.

The effect of etching for 5 seconds with a dilute solution of copper sulfate is shown in Figs. 7 and 8. Precipitation of metallic copper occurs on wüstite but not on fayalite. It is possible that very small particles of metallic iron with a diameter of about 0.001 mm. may occur distributed throughout the wüstite. The appearance of the metallic iron, after etching with 2.5%

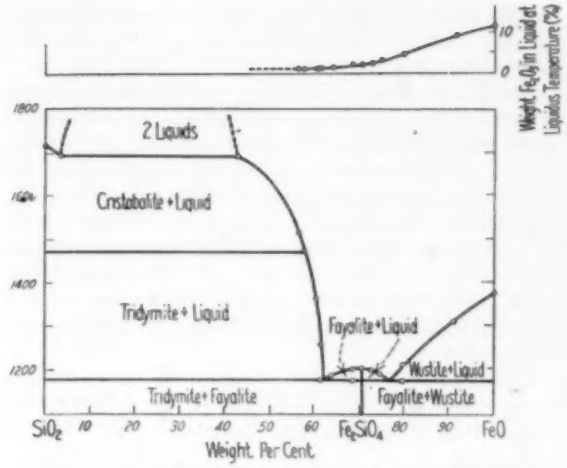

FIG. 5.—Equilibrium diagram of the system FeO–SiO_2, constructed by calculating all iron oxides in the liquids to FeO (after Bowen and Schairer, see footnote 5.).

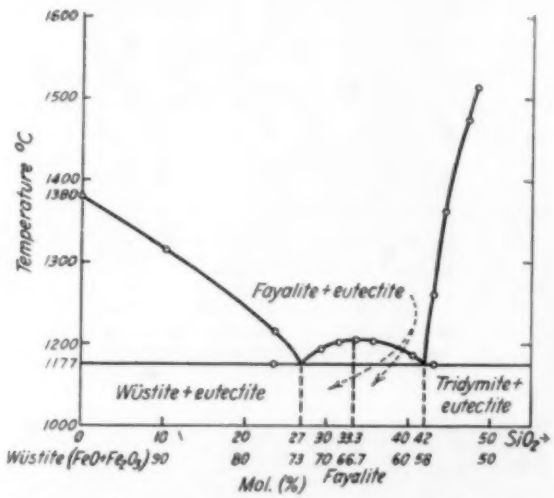

FIG. 6.—Equilibrium diagram of the system wüstite–silica, constructed by recalculating the data of Bowen and Schairer, *Amer. Jour. Sci.*, Sept., 1932 (Table II).

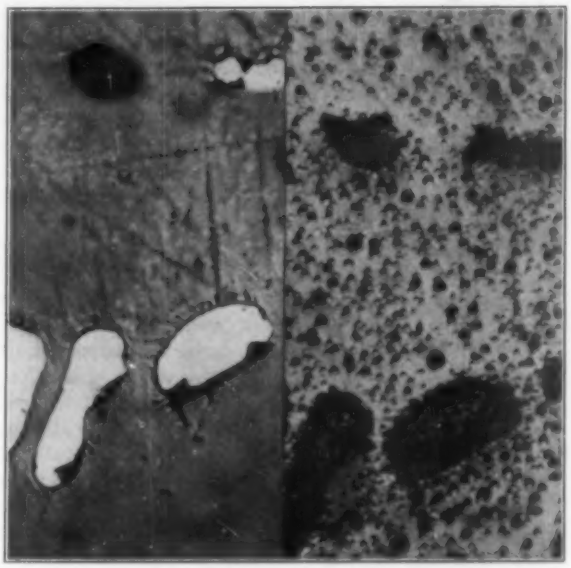

FIG. 7.—*Left*, slag No. 32, polished section, 1000×; area selected for study of effect of $CuSO_4$ etch; appearance before etch.

FIG. 8.—*Right*, slag No. 32, polished section, 1000×; appearance after 5 seconds etch with dilute $CuSO_4$ solution; note precipitation of copper on spots in the wüstite.

FIG. 9.—Slag No. 32, polished section, 1000×; Nital etch. Metallic iron (high luster) surrounded by fayalite, in a wüstite matrix.

Nital, is shown in Fig. 9. Specimens of naturally occurring magnetite and hematite treated with copper sulfate solution, even for several minutes, showed no signs of copper precipitation.

As a final test of the identity of the magnetic metallic-appearing particles, a number of these (0.5 mg. in weight) with an average diameter of about 0.15 mm. were treated with 1 to 1 HCl, and the particles were dissolved with evolution of gas (hydrogen from metal). After oxidizing with a drop of HNO_3 and boiling and cooling, a typical precipitate of ferric hydroxide was obtained with NH_4OH. This precipitate was collected on a very small ashless filter paper, washed, and ignited in platinum. The ignited residue weighed 0.835 mg. The theoretical weight of 0.5 mg. of metallic iron, when converted to Fe_2O_3, is 0.715 mg. It seems then that the metallic particles without doubt were metallic iron. Wohrman[7] shows similar inclusions in iron oxide

[7] C. R. Wohrman, "Inclusions in Iron," *Trans. Amer. Soc. Steel Treating* (1928); p. 25, Fig. 13.

which he designates as metallic iron, but he does not state his method of identification.

It must be remembered, however, that the melts were made in Armco iron crucibles, so that at no time could the temperature have exceeded the melting point of this element. The mechanism of the formation of the metallic iron in the slags will be discussed later (see Section V (3), p. 331). (Owing to gravity separation, there might be a tendency for a concentration of these metallic-iron particles toward the bottom of the melt, but no such tendency was observed.) The fact that no tendency toward such segregation occurred may be explained by considering the viscosity and relatively high density of a slag consisting largely of wüstite and also the relatively small size of the iron particles. Apart from the metallic iron, the primary crystallization apparently is that of wüstite, which during its solidification seems to have pushed the metallic iron particles toward the grain boundaries where the fayalite-wüstite eutectic finally crystallized, surrounding the particles of metallic iron. It may be calculated that the primary wüstite in slag No. 32 consists of 94.5 mol. % FeO and 5.5 mol. % Fe_2O_3.

Slags Nos. 33, 34, and 103: These slags have a general constitution, similar to those previously described. Because of their higher silica content, their content in free wüstite is progressively lower and their content in eutectic is progressively higher.

Slag No. 100: The silica content of this slag is 22.96% by weight or 27.19 mol. %. This slag falls close to the eutectic between wüstite and fayalite (Fig. 6). It is calculated that it contains 2.69 mol. % free fayalite and consequently no free wüstite. This calculation is justified by the structures shown in Fig. 10 in which the light areas are eutectic wüstite and the dark areas, fayalite (reflected light); the excess fayalite is clearly shown.

Slags Nos. 104, 105, 101, and 106: These slags contain sufficient silica so that they fall within the second of the two eutectiferous series present in the general series iron oxide–silica. This second series is between fayalite and tridymite. Slags Nos. 104, 105, and 101 fall on the "excess fayalite" side of the eutectic; slag No. 106, containing 51.5 mol. % silica, falls on the excess tridymite side. Slag No. 101 has a composition close to that of the eutectic. All the slags of this series (fayalite-tridymite) contain magnetite, and this constituent can be detected readily by microscopic examination.

The mode of occurrence of this magnetite presents some points of interest. Magnetite (high luster) occurs closely associated with tridymite, with which it

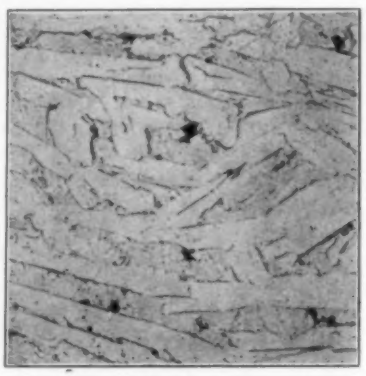

FIG. 11.—Slag No. 104, polished section, 100×; general structural features; fayalite crystals in background of fayalite-tridymite eutectic.

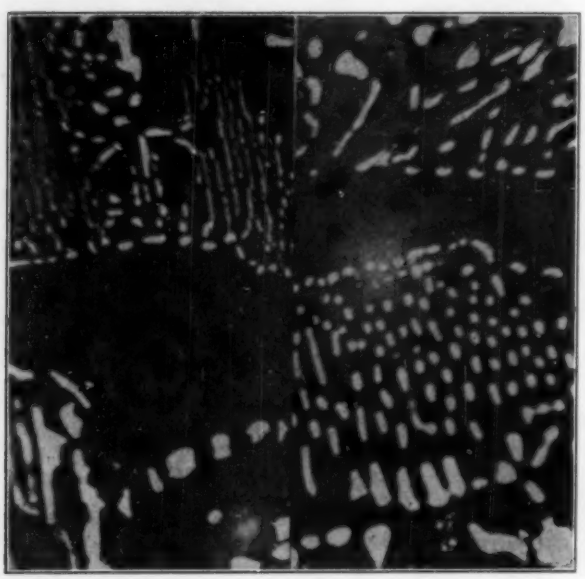

FIG. 10.—Slag No. 100, polished section, 1000×; wüstite-fayalite eutectic with excess fayalite.

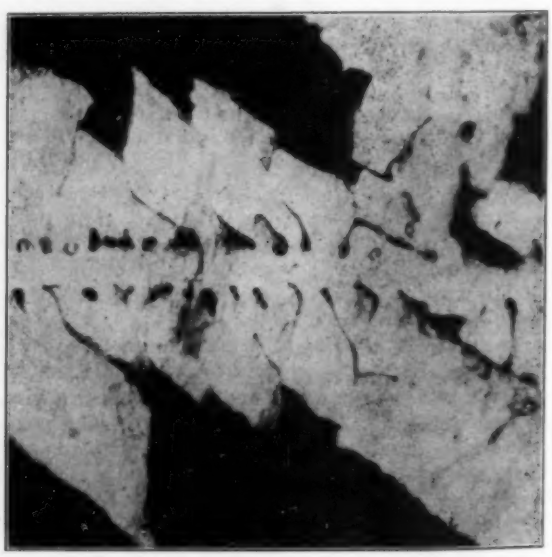

FIG. 12.—Slag No. 104, thin section, 1800×; fayalite crystal.

seems to form a eutectiferous structure entirely apart from the general fayalite-tridymite eutectic. In slag No. 106, however, which contains free excess tridymite, this phenomenon is not so apparent.

An explanation of the general occurrence of magnetite in the series fayalite-tridymite and its absence in the series wüstite–fayalite is offered as follows:

In the wüstite-fayalite series, FeO is capable of dissolving and holding in solid solution considerable quantities of Fe_2O_3. This solid solution has been called wüstite.

The calculated composition of the wüstite as related to the silica content of the slags is given in Table III.

TABLE III

COMPOSITION OF WÜSTITE

Slag No.	Mol. % SiO_2	Mol. % FeO	Mol. % Fe_2O_3
102	0.04	95.30	4.70
32	0.78	94.54	5.46
33	3.22	94.50	5.50
34	4.69	93.63	6.37
103	11.96	93.33	6.67

This table shows that as the silica content of the slag increases, there is a gradual increase in the Fe_2O_3 held in solid solution in the FeO; in general, however, the ratio of FeO to Fe_2O_3 is fairly constant.

The fact that no magnetite, as such, appears to be present in these slags indicates that FeO is capable of holding certain quantities of Fe_2O_3 (or perhaps magnetite) in solution and that, as far as these slags are concerned, the saturation point has not been reached.

(2) Formation of Magnetite

In slags Nos. 104, 105, 101, and 106, the silica is high enough to combine with all available FeO, so that no excess wüstite is formed. Nevertheless, the Fe_2O_3, having a greater affinity for FeO than has silica, unites with its proportion of FeO and appears as magnetite. The actual composition of this magnetite was not determined although it was identified with considerable certainty by a study of particles magnetically separated from the finely powdered slag. Chemical separations of magnetite in the presence of fayalite present difficulties because of the ready solubility both of fayalite and magnetite in ordinary acids. Owing to the physical constitution of the slags, even the finest grinding precludes magnetic separation. Although a "tailings" substantially free from magnetite can be produced, the "magnetic" concentrates are contaminated to such a degree as to be useless for the purpose intended.

In the case of a slag falling in the fayalite-tridymite series and containing no Fe_2O_3 (if such a slag could be produced), the normal process of solidification would be for a hypoeutectic first, *i.e.*, the crystallization of excess fayalite until the composition of the mother liquor had reached the eutectic composition (42 mol.% SiO_2); then the eutectic consisting of fayalite and tridymite would freeze at about 1177°C. In the case of hypereutectic slags, the solidified material would consist of excess tridymite and eutectic.

The presence of Fe_2O_3 in the slag would seem to upset this normal process of solidification. A microscopic study of slags Nos. 104, 105, 101, and 106 showed that (*a*) magnetite always occurs closely associated with tridymite; (*b*) tridymite occurs in two forms, *viz.*, that associated with magnetite and that forming eutectic with fayalite; (*c*) *all* the magnetite occurs surrounded by tridymite; and (*d*) magnetite itself occurs in two forms, *viz.*, as organized crystals or crystallites and in a "eutectic-like" form with tridymite.

To explain these two forms of occurrence of magnetite, it seems necessary to propose that cristobalite is capable of holding a certain quantity of magnetite in solid solution and that when cristobalite, upon cooling, transforms into tridymite at about 1480°C this solid solution, magnetite, is thrown out of solution and appears as the "eutectic-like" form with tridymite. In other words, magnetite is soluble in cristobalite but insoluble in tridymite, and this gives the analogy to the relative solubilities of iron carbide in gamma and alpha iron. It is well known that in the metallography of steel, Fe_3C is soluble in gamma iron and insoluble in alpha iron with which it forms pearlite on slow cooling.

The melting point of magnetite is given by Hilpert and Kohlmeyer,[8] and quoted by Mathewson,[9] as 1527°C.

To form magnetite, the Fe_2O_3 in the slag unites with FeO from the surrounding molten fayalite, setting free an equal number of molecules of silica (as cristobalite). This action may be illustrated by the following equation:

$$Fe_2O_3 + 2FeO{\cdot}SiO_2 = FeO{\cdot}Fe_2O_3 + SiO_2 + FeO.$$

The solid cristobalite precipitated by this action, however, is capable of holding a certain amount of magnetite in solid solution. When the slag has cooled to the

[8] S. Hilpert and E. G. Kohlmeyer, "Über Calcium Ferrite," *Ber. deut. chem. Ges.*, **42**, 4581–94 (1909).

[9] C. H. Mathewson, E. Spire, and W. E. Milligan, *Trans. Amer. Soc. Steel Treating*, **19** [1] 66–88 (1931).

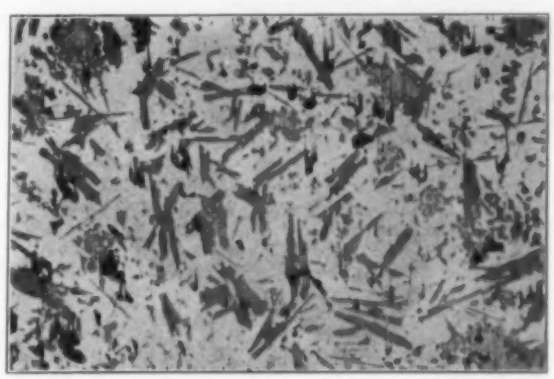

FIG. 13.—Slag No. 105, polished section, 100×; general structural features; fayalite and fayalite-tridymite eutectic.

FIG. 14.—Slag No. 105, thin section, 1800×; fayalite crystallite with fayalite-tridymite eutectic.

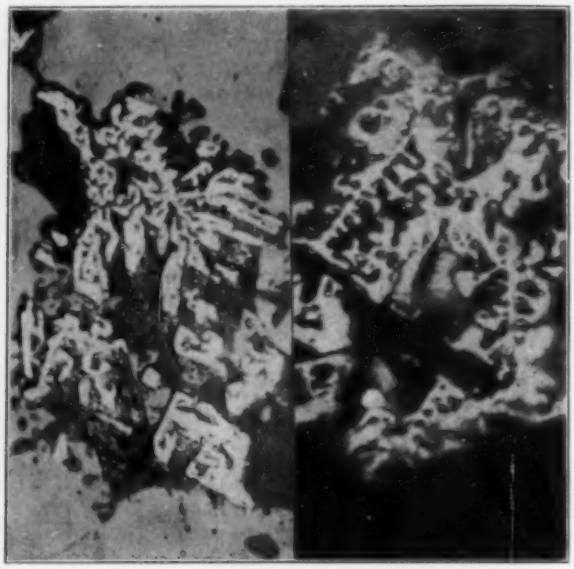

FIG. 16.—*Left*, slag No. 106, polished section, 1000×; tridymite (dark), magnetite (high luster), and fayalite-tridymite eutectic; *right*, slag No. 106, polished section, 2000×; details of magnetite crystallite.

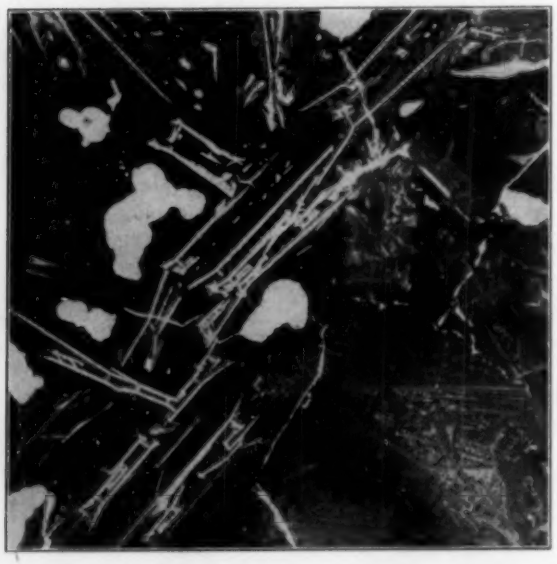

FIG. 15.—Slag No. 101, thin section, 10×; general structural features; largely fayalite-tridymite eutectic.

transformation temperature of cristobalite → tridymite (*circa*, 1480°C), this "solid solution" magnetite crystallizes in "eutectoid" form with tridymite.

After the formation of the magnetite with its accompanying "prematurely precipitated" tridymite (cristobalite), excess fayalite (or excess tridymite) crystallizes until the eutectic composition of the mother liquor is reached; the eutectic then freezes and the slag is completely solid.

The presence of Fe_2O_3, with the consequent formation of magnetite and the accompanying premature precipitation of cristobalite, upsets the normal ratio of excess fayalite (or excess tridymite) to eutectic in the solid slag if this ratio is calculated from the diagram (Fig. 6) wüstite-silica. In calculating the final structural composition of a slag falling in the partial series fayalite-tridymite, this should be taken into account. This may be illustrated by comparing the calculated structural composition of slag No. 101 (see Table I), in which the prematurely precipitated silica was not taken into account, with the calculated structural composition when this correction was made.

TABLE IV

STRUCTURAL COMPOSITION OF SLAG NO. 101

	Mol. % (*a*)	Mol. % (*b*)
Fayalite-tridymite eutectic	92.50	84.78
Excess fayalite	4.42	9.75
Magnetite	2.39	2.39
Metallic iron	0.69	0.69
Tridymite (eutectoid)		2.39

Composition (*b*) in Table IV was calculated, taking into account the precipitation by magnetite of equal molecules of tridymite. Microscopic examination of the general structure of slags in the tridymite-fayalite series justifies this method of calculation. In other words, the presence of Fe_2O_3 and the formation of magnetite results (in the case of hypoeutectoid slags)

in the formation of a larger amount of excess fayalite than is called for by the general constitutional diagram.

(3) Occurrence of Metallic Iron

Metallic iron was found to occur in all of the slags melted in iron crucibles. Chaudron[10] and Eastman[11] found that ferrous oxide, prepared at high temperature, becomes unstable on cooling and partly decomposes as follows:

$$4FeO = Fe_3O_4 + Fe.$$

Wohrman[7] and Mathewson[9] show numerous micrographs of slags in which metallic iron is a constituent, and Wohrman agrees with Matsubara[12] that Fe_3O_4, simultaneously formed, is soluble to some extent in FeO. A possibility seems to exist, however, wherein the equation might be written $3FeO = Fe_2O_3 + Fe$ because it seems preferable to consider magnetite to have the formula $FeO \cdot Fe_2O_3$ rather than Fe_3O_4.

As the silica content increases (1) there is a gradual falling off in metallic iron content; (2) although the amount of metallic iron decreases approximately with the decrease in Fe_2O_3 content, no quantitative ratio seems to exist between the two; and (3) metallic iron is still found in slags containing no excess wüstite. As will be shown later, when mixtures of iron oxide are melted in siliceous crucibles, no metallic iron could be detected in the resulting slags. This would indicate that the presence of metallic iron, *e.g.*, in the crucible walls, is a necessary condition for the formation of metallic iron in the slag. In this connection, it is of interest to investigate the structure of slag inclusions in wrought iron. Figure 17 shows such an inclusion at 1000×. In this photomicrograph, the whole field is occupied by a part of a large slag inclusion found in a piece of Swedish wrought iron. The matrix apparently is iron oxide (wüstite). The dark areas are silicate, having the same general appearance as fayalite but probably containing manganese oxide and other bases. The presence of the high luster constituent should be noted (marked with arrows). It was identified as metallic iron, and it was always found to be associated with the silicate in the same manner as the metallic iron occurs with fayalite in the synthetic slags.

It seems to be justifiable to suppose that the presence of metallic iron, *e.g.*, as a crucible or as in the puddling furnace, is an essential condition for the production of metallic iron in the slag itself. It also appears probable that the equation, $4FeO = 3Fe_2O_4 + Fe$, induced by heating FeO to a high temperature, was not the only factor in the formation of metallic iron. If this condition holds universally, then metallic iron should have been obtained in the iron-oxide melts conducted in siliceous crucibles. Slag No. 112, formed in a siliceous crucible and containing a comparatively low percentage of silica, showed no content in metallic iron.

VI. Neutral Atmosphere vs. Oxidizing Atmosphere in Melting

In the endeavor to form the largest possible proportions of FeO and the least Fe_2O_3, most investigators of the series iron oxide–silica have resorted to the use of iron crucibles together with vacuum melting or melting in a neutral atmosphere. Bowen and Schairer[5] used the latter method, making use of purified nitrogen. The present writer particularly wished to avoid such conditions and to melt the slag mixtures with free access of oxygen so that the conditions would more nearly simulate practical furnace operation. In previous publications, the writer has decried the use of data obtained by vacuum or neutral atmosphere melting in connection with the consideration of practical steelmaking slag reactions. Because of the frequency with which such data have been used, a comparison of the results of Bowen and Schairer (obtained in nitrogen atmosphere) and the results of the writer (obtained with open crucibles in a strongly oxidizing atmosphere) are presented in Fig. 19, on which the weight percentages of SiO_2, FeO, and Fe_2O_3 of the two sets of slags are plotted.

Bowen and Schairer did not report the percentage of metallic iron in their slags, although some iron in this form probably existed. It is probable that the metallic iron, if any were present, would appear in their

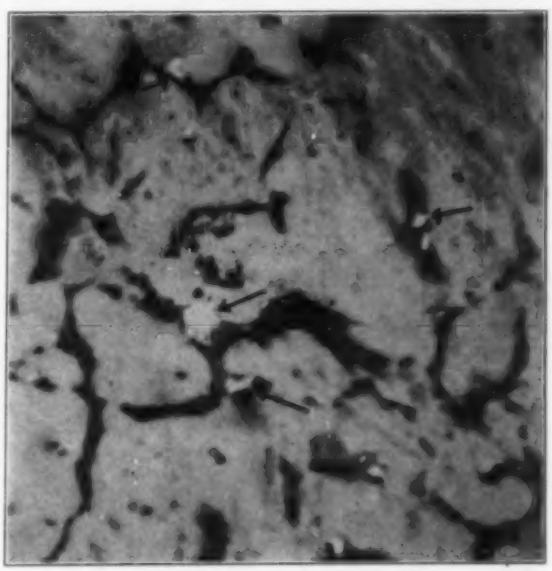

FIG. 17.—Slag in wrought iron, polished section, 1000×. The whole field is occupied by part of a large slag inclusion in a piece of Swedish wrought iron; the matrix apparently is wüstite; dark areas are silicate; high luster constituent is metallic iron (marked with arrows), which is always associated with silicate in a manner similar to its occurrence in artificial slags of the same general character (slags Nos. 32, 33, and 34).

[10] G. Chaudron, "Réactions Réversibles de l'Oxyde de Carbone sur les Oxydes de Fer," *Compt. Rend.*, **172**, 152 (Jan.–June, 1921).

[11] E. D. Eastman, "Equilibria in the System Iron–Oxygen and Iron–Hydrogen–Oxygen," *Jour. Amer. Chem. Soc.*, **44**, 975–98 (1922).

[12] A. Matsubara, *Trans. Amer. Inst. Mining Met. Engrs.*, **67**, 3 (1922).

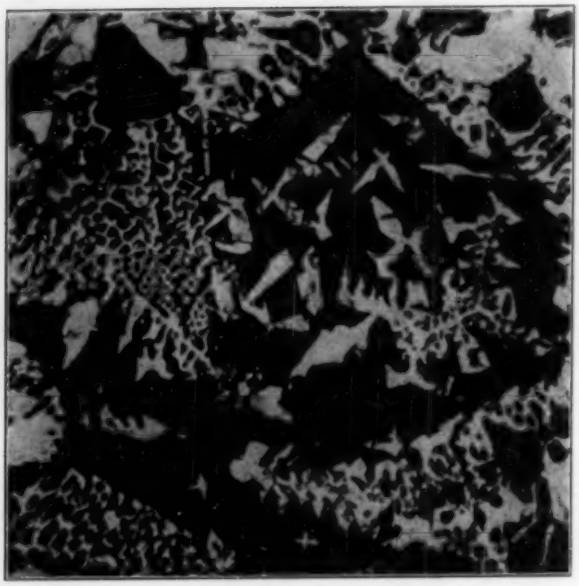

FIG. 18.—Slag No. 112, polished section, 1000×; magnetite (high luster) and tridymite.

analytical results as FeO. To have comparable results, the analyses have been recalculated on the same basis for purposes of this diagram.

The comparison shows a remarkable coincidence of results, and as far as slags of this particular range of composition are concerned, the elaborate precautions taken by many investigators to insure maximum production of FeO apparently are of little avail. The strong reducing power of metallic iron of the crucibles greatly overshadows any oxidizing effect of the atmosphere in which the melts are prepared. Another point worthy of mention is that several writers have stated that in slags in the molten condition, all the iron is present in the form of FeO and that any Fe_2O_3 found by analysis is due to oxidation during solidification.

This point of view is stated by Mauer and Bischoff.[12] Sisco[14] does not indicate any direct method for FeO determination; he contents himself with calculating the total iron as determined by ordinary methods in terms of ferrous oxide.

A number of similar opinions may be found in literature. As far back as 1895, Ledebur[15] stated that in molten slags all the iron was in the ferrous state and that ferric oxide could not exist in contact with iron at elevated temperatures.

The comparison of the results of the writer with those of Bowen and Schairer tests the validity of these opinions because, although almost identical amounts of Fe_2O_3 were obtained in the two series, the slags prepared by Bowen and Schairer were instantaneously quenched in mercury from temperatures just under their melting points, while the slags in this study were slowly furnace-cooled.

This matter of the existence or nonexistence of Fe_2O_3 in molten slags has been emphasized because of the particular methods of study which the writer has used and will continue to use in connection with the investigation of slags; these are chemical analysis and petrographic examination. If it is true that the molten slags contain iron only in the ferrous form, then the results of the present studies would have a somewhat limited value when applied to actual steelmaking operations.

VII. Melting in Siliceous Crucibles

A series of experiments was conducted in which the Armco iron crucibles were replaced by Battersea (siliceous) crucibles. The particular object was to establish the point of partition of iron oxides on the edge (Fe_2O_3–FeO) of the representative tetrahedron, under conditions of free oxidation and without the presence of metallic iron.

The only complete melt obtained was in the case of slag No. 112. Slags Nos. 110 and 111 were simply friable sinters, easily crushed to a fine powder between the fingers. Microscopic examination of this powder revealed separate grains of magnetic oxide and silica. Little or no chemical action could be detected. Slag No. 112 showed a definite melting point at 1530°C and formed a distinctly liquid melt at 1600°C. After furnace cooling, a compact solid material was available for the preparation of microscopic specimens.

Although the major portion of the sample was readily soluble in strong HCl, a very insoluble residue remained. It was considered to be possible that a separation of mineral constituents could be made by acid treatment.

To this end 7 grams of 150-mesh slag were treated with successive portions of warm, strong HCl, decanting each portion through a filter paper. When no further coloration of the acid was obtained, the residue was transferred to the filter and washed free from chlorides. After drying at 120°C, it was found that

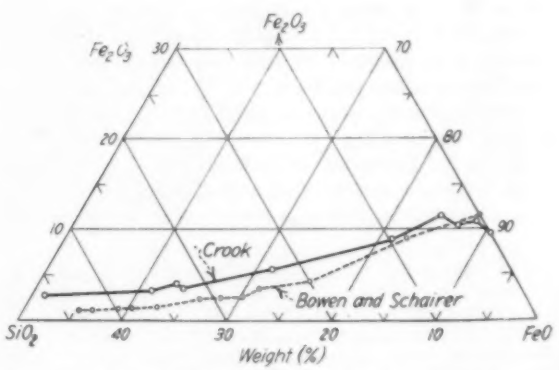

FIG. 19.—Composition of iron oxide–silica melts in iron crucibles.

[13] E. Maurer and W. Bischoff, "Distribution of Phosphorus Between the Metal and the Slag in Basic Processes of Steel Manufacture," *Jour. Iron Steel Inst.* [London], **132**, 13–43 (1935).

[14] F. T. Sisco, Analysis of Steel, 1st ed., pp. 478–79. McGraw-Hill Book Co., New York, 1923.

[15] A. Ledebur, Métallurgie du Fer, Vol. II, p. 576 (1895).

0.7712 gram of residue had been obtained from 7 grams of slag. Both the solution from the soluble portion and the insoluble residue were analyzed.

Calculated on the basis of one gram of slag, the following amounts of soluble and insoluble constituents were found:

	Original analysis	By acid treatment (1 g.)	
	Weight (%)	Soluble (g.)	Insoluble (g.)
SiO_2	8.61	None	0.0861
FeO	24.90	0.2420	0.0070
Fe_2O_3	62.05	0.6164	0.0041
Al_2O_3	1.00	None	0.0100
	96.56	0.8584	0.1072

A spectroscopic analysis of the residue insoluble in HCl revealed silicon, iron, titanium, aluminum, magnesium, calcium, sodium, manganese, and copper.

The titanium was very prominent, and copper was present only as a spectroscopic trace. It may be inferred therefore that the 3.44% lacking in the slag analysis consists largely of titanium, magnesium, calcium, and perhaps sodium oxides.

VIII. Microscopic Examination

(1) Polished Section (Reflected Light)

Micrographs of the polished section of slag No. 112 are shown in Fig. 18 at 1000×. The specimen was found to consist of magnetite, crystallized in typical form (fer de lance). These crystals are set in a dark-colored matrix (reflected light) which has the general appearance of a silicate but not of fayalite. The magnetite undoubtedly is of primary crystallization. At 1000×, there is a suggestion of a structure in the dark constituent which is somewhat transparent, but it does not have the light yellow tinge and the degree of transparency exhibited by fayalite under reflected light.

When much added silica is present, melting tends to be prohibited and no chemical reaction will result other than that of conversion of the iron oxide to magnetite.

(2) Strewn Powder Section of Insoluble Residue

The particles on the slide were found to consist of fragments of tridymite crystallite as well as of fragments of a silicate having a dark brown color which had an appearance entirely different from fayalite. These particles often contained typical crystallites of tridymite in addition to what appeared to be a eutectic structure composed of colorless silica and the dark brown component. This eutectic-like structure was of extremely fine texture, and it could be observed only at the highest magnifications. It is believed that the dark brown constituent, which occurred in relatively small amount considering the slag as a whole, is a complex silicate containing alumina, titania, lime, magnesia, etc. (see results of spectrographic analysis).

(1939)

IX. Discussion of Slag No. 112

This slag shows a structure which is of considerable importance in revealing the mechanism of solidification of melts made from iron oxide and silica in siliceous crucibles.

Consideration of the analysis of the matrix (insoluble residue) shows that the iron oxides present in the slag occur almost wholly as magnetite. The insoluble portion of the slag contains only 7.3% total iron, and the residue is only 10% of the slag. It seems probable that if the Al_2O_3, TiO_2, etc., picked up from the crucible walls had not been present, the insoluble portion would have been wholly tridymite.

The magnetite did not contain an equal molecular proportion of FeO to Fe_2O_3, the ratio being 1.00 FeO to 1.127 Fe_2O_3. As has been shown in sinters produced at various temperatures, the higher the temperature to which the iron oxide was heated, the closer the approach of the ratio of the two oxides to equality of molecular percentages.

At the melting point (1530°C), the molecular proportions of FeO and Fe_2O_3 begin to approach unity. At a temperature of about 1700°C, it is probable that a unity ratio will be reached.

X. Summary

In general terms, it may be said that when iron oxide and silica are heated to 1600°C or above in a siliceous crucible, the resulting slag consists essentially of tridymite and magnetite, the latter having a composition approaching $FeO{\cdot}Fe_2O_3$, the affinity of Fe_2O_3 for FeO being so strong that little or no FeO is able to unite with SiO_2 to form fayalite or other silicate.

This condition is far different from that when iron crucibles are used with the resulting production of large quantities of ferrous oxide much in excess of that required to unite with ferric oxide to produce magnetite.

Consideration of the entire series of slags described here brings to attention the fact that ferric oxide has a much greater affinity for ferrous oxide than has silica. Even in the case where iron crucibles were used and where an excess of silica was present, magnetite was formed in preference to fayalite.

It is interesting to note that if a limiting temperature of 1600°C is used to produce the melts (iron oxide-SiO_2) in siliceous crucibles, slags containing lower than about 8% silica are difficult to produce. If silica is added to the original iron-oxide charge, only sintering results. If the pure iron oxide is heated to temperatures below about 1530°C, melting does not occur and little or no silica is taken up from the crucible walls.

The question arises as to whether or not, once an iron-oxide silica slag has been formed by melting in an iron crucible, the composition will be changed by remelting in a siliceous crucible. In other words, will a slag once formed in the presence of iron change its degree of oxidation when the reducing influence of iron is removed?

Slag No. 109 represents the result of an experiment to elucidate this point. A portion of slag No. 106, melted in an iron crucible, was ground through a 150-mesh screen and remelted in a siliceous crucible.

In general, no great change occurs on remelting. There is some increase in Fe_2O_3, however, as well as a small pick-up of silica from the crucible. No metallic iron could be found in the remelted slag. The increase in Fe_2O_3 is reflected in the increase in magnetite. It is apparent that once fayalite has formed (in the presence of metallic iron), remelting without the presence of iron does not appreciably oxidize this silicate.

Acknowledgment

The author wishes to express his appreciation of the interest and generosity of Research Corporation in assisting in the acquisition of certain of the apparatus and supplies needed to carry out this work. The experimentation was conducted in the metallurgical laboratories, Department of Mining Engineering, Stanford University. The assistance given by John R. Cunningham, graduate student, Department of Mining Engineering, Stanford University, in connection with certain phases of this study is also acknowledged with appreciation.

Department of Mining Engineering
Stanford University
Stanford University, California

A CRITICAL EXAMINATION OF THE LOAD TEST FOR REFRACTORIES*

By F. H. Norton

Abstract

Methods and equipment are described for making long-time load tests on refractories similar to creep tests for metals. A uniform flow rate is not established until approximately 100 hours have elapsed and shorter tests give load values considerably lower than can be used safely in design work. It is suggested that a long test of this type would be a more satisfactory standard than the short test now used.

I. Introduction

The usual load test for refractories has been carried out as a dynamic test, *i.e.*, the temperature has been increased continuously to a maximum and held at a constant value for an interval too short to reach complete equilibrium conditions. The results of such dynamic tests, which have value in determining the relative merits of various brick, obviously are not suitable to provide data for the designer of furnaces in which the brick is subjected to long, continued temperatures and loads. Nearly all furnace designers have found that in fixing allowable loads there is only experience to guide them. It is therefore necessary to study the possibility of providing a static test of such a character that valuable design data on any particular brick may be obtained. Such a test, based on the methods used in measuring the creep of steel, has been worked out in the Institute laboratories during the past three or four years. A general discussion of this problem was given by the author[1] some time ago, and a description of the particular equipment and testing methods is presented here.

II. Description of Furnace

A general description of the furnace for making these load tests has been described recently.[2] Globar heating units were selected because they give excellent control, but other types of heating may be used. Because the furnace is lined with insulating refractories, the uniformity of temperature is excellent, and the readings over the brick do not vary more than ±5°F. The general layout of the furnace needs no particular comment.

The temperature control may be of interest, however, because it gives particularly good results with this type of furnace. The general setup of this control system is shown in Fig. 1. The control element is a radiation pyrometer connected to a potentiometer and a reflecting galvanometer. A beam of light is reflected from the galvanometer mirror onto a photocell which operates a relay. This relay is connected to the field circuit of the exciter for a motor-generator set in such a way that the voltage of the generator is increased 10% when the relay is closed, using the usual Ward-Leonard control.

The operation of this control system is simple. As soon as the furnace temperature rises more than 4° above the equilibrium value, the galvanometer is deflected from its zero point and throws the light beam off the photocell, opens the relays, and reduces the voltage to the furnace 10%. This immediately starts cooling the furnace, and the temperature drops until it reaches 4° below the equilibrium point; the light beam is

---

* Presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 19, 1939 (Refractories Division). Received March 29, 1939.

[1] F. H. Norton, "Flow of Ceramic Bodies at Elevated Temperatures," *Jour. Amer. Ceram. Soc.*, 19 [5] 129–34 (1936).

[2] C. L. Norton, Jr., and V. P. Duplin, Jr., "Deformation of Insulating Fire Brick under Load." Paper presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 19, 1939 (Refractories Division). This paper will be published later in the *Journal*.

shifted onto the photocell, which in turn closes the relays and again increases the current. This regulating cycle is comparatively short and the setup has been found to be particularly reliable over long periods of time, some runs lasting four weeks with the temperature always within the limits set.

The temperature of the furnace is measured by a platinum thermocouple placed between the two test brick. It is connected to a separate potentiometer in the usual way with the cold junction in ice.

The standard load test measures the total deformation of the brick at the end of the run. In this test, however, it is desirable to record the change in length more or less continuously, and for this purpose an apparatus has been devised similar to that used for the creep measurement of steel (Fig. 2). A pair of micrometer telescopes, mounted upon a rigid slide on 9-inch centers, sight through tubes in the furnace wall at the top and bottom of the test brick itself. To give a good reference mark, the test brick as well as the brick above and below it have a shallow notch in the ends parallel with the telescopes (Fig. 3). A No. 26 platinum wire is placed across this notch, which gives an excellent reference mark permitting length changes to be read within ten parts in a million. A pair of tubes on the opposite side of the furnace from the telescope provides a darker background against which the platinum wire stands out clearly.

The loading of the brick is carried out by a simple lever system and requires no particular discussion.

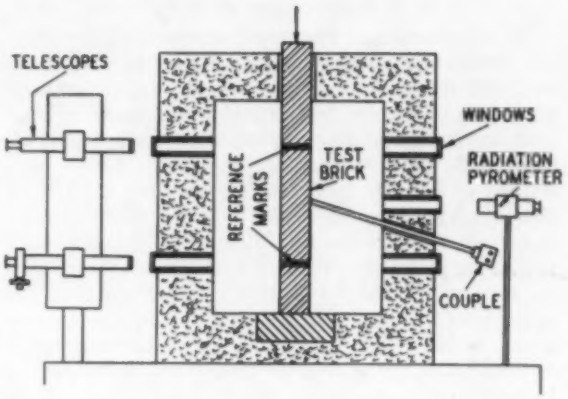

FIG. 2.

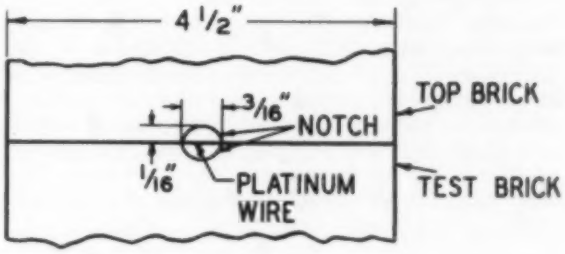

FIG. 3.

III. Method of Conducting the Test

The test brick are selected to have true ends, and a shallow groove is cut at the end of each with a silicon carbide saw to provide the sighting mark. They are then placed in the furnace in the usual manner with the platinum wire carefully lined up. A very light load is applied to hold them in place, and the furnace is heated up comparatively rapidly so that the maximum temperature is reached in about 2 hours. The automatic control system is put into operation, and this temperature is held until complete temperature equilibrium is reached, which takes another 6 to 12 hours. The required load is then applied, and length readings are taken at definite intervals. If the rate of flow is rapid, these intervals may be as short as 10 or 15 minutes; if the rate of flow is slow, a daily reading is sufficient.

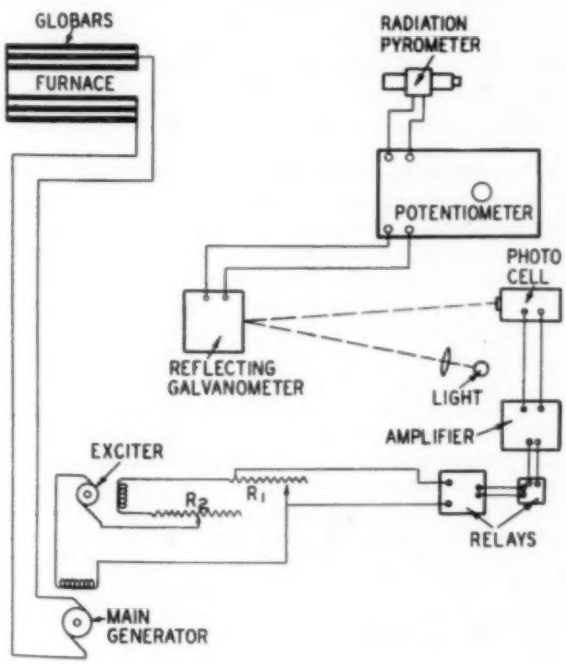

FIG. 1.

IV. Calculations

These elongation readings are computed in percentage of the length of the brick and plotted against time (Fig. 4) for a typical insulating refractory at 2270°F. The precision of this test is ample for the purpose, inasmuch as the experimental points follow closely on a smooth curve. When curves of this type are made on the same kind of brick at several loads, the rate of flow in the steady state may be plotted against stress. When plotted on a log-log sheet, it will be found that over the useful range a straight line results as in creep tests on steel (Fig. 5). It should be recognized that this log-log plot is simply an empirical relation and has no theoretical significance; it is convenient, however, for interpolation.

V. Application of Results

An examination of Fig. 4 will show that the refractory flows comparatively rapidly in the first part of the test, and the data taken in this period give loadings much lower than the brick could safely carry in long-time service. The flow, in fact, does not become uniform with most refractories until 100 hours have elapsed. The static load test, carried until the rate of flow is uniform, therefore is the only way in which satisfactory design data can be obtained. If it is necessary to find the permissible load for a certain refractory used as a partition wall of a heat-treating furnace, the amount of deformation permissible and the desired length of service before replacement are first estimated. It is necessary, of course, to assume a uniform flow of from 500 to 10,000 hours. This would seem to be an unjustified exterpolation except that creep data on steel have been obtained for more than this time interval, showing absolute uniformity of flow.

For example, let the life be 10,000 hours and the maximum compression 10%, giving a flow rate of 1% per 1000 hours. From Fig. 5, it is seen that a loading of 0.8 lb. per sq. in. gives the allowable flow rate. This does not take in the more rapid initial flow, which in this case will amount to 0.08% (Fig. 4), a negligible amount.

VI. Modifying Factors in Furnace Construction

Nearly every one who has had occasion to design furnaces has been impressed by the small number of cases in which refractories actually fail by deformation under load even when they are stressed to a point where they would show comparatively rapid flow in the load test. It is obvious, however, that only a few furnace parts, such as piers and partition walls, are heated through uniformly; even in these cases the core may be at a somewhat lower temperature than the surface caused by conduction down through the floor or because the furnace is used intermittently and the temperature cycle is so short that complete equilibrium is never reached.

VII. Factor of Safety

It is the general practice in engineering structures to add a factor of safety to the designed loads to take care of variations in the material, reduction of cross section by corrosion, and unexpectedly large loadings. When the design is carried into the high-temperature field, as in high-pressure boilers and oil stills, the instantaneous strength of the materials is found to be so much greater than the allowable load placed on them by flow characteristics that the factor of safety can be reduced or even completely eliminated. It is considered good practice to design in the high-temperature field with a stress of two thirds of that computed from the creep strength, and in some cases the design stress is computed directly from the creep strength.

In the case of refractories, there is somewhat the same condition, *i.e.*, the instantaneous strength under momentary loads is very high compared with the allowable stress causing continuous flow. The question of factor of safety would not enter in most cases therefore because the load dictated by the flow rate might well be used directly. In furnaces in which slag attack reduces the section of the brick, some allowance should be made for this factor.

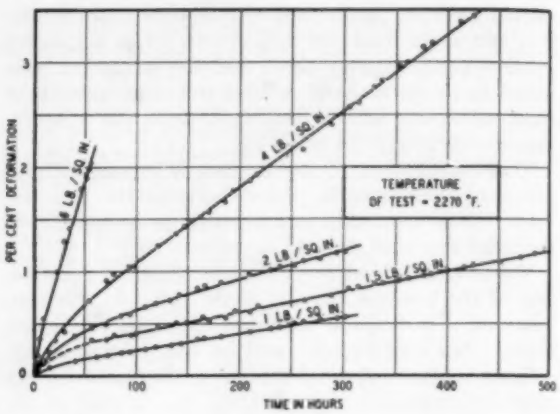

FIG. 4.

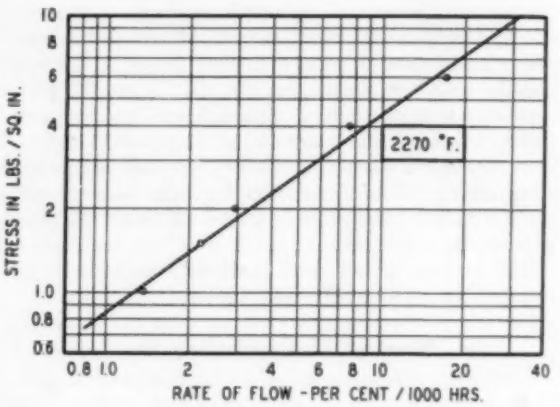

FIG. 5.

VIII. Standard Load Test for Continuous Flow

There is some doubt that the rate of flow of a refractory in the first few hours bears a definite relation to the final rate of flow after equilibrium has been established. The load test now used should be revised to test a brick long enough to measure the steady flow rate. It would be impractical to test a given brick at several loads and temperatures for a long period, but a definite temperature and load could be set up for each classification of brick and a certain maximum allowable flow rate specified for each class. A test of 300 or 400 hours would be more expensive than the standard load test, but the time required for the readings amounts only to a few minutes a day if a temperature controller is used; the results are of enough value to justify the additional expense. In spalling tests, the simple and inexpensive test on single brick did not give sufficient correlation with service results to justify its use compared with the more expensive panel spalling test.

DIVISION OF CERAMICS, DEPARTMENT OF METALLURGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS

OBSERVATIONS ON THE SLAGGING OF SOME GLASS FURNACE CHECKERS*

By W. L. Fabianic

Abstract

Two brands of super-duty fireclay brick with similar physical and chemical properties were selected. These two brands were put into opposite regenerators of the same commercial furnace melting a soda-lime glass. One brand failed before the furnace campaign was completed and the other did not. Investigation showed that one of the main differences between the two brands was the amount of microscopically visible mullite crystals present.

I. Introduction

Considerable work has been done in the past few years on the study of alumina-silica checker brick for use in glass-furnace regenerators. Several pieces of thorough and fruitful research work have been published on the slagging, slabbing, and crusting over of all types of alumina, silica, and high-alumina checkers. The microstructure, chemical, and physical properties of various brick have also been thoroughly investigated. The present paper thus treads on familiar ground, but as the author is pessimistic enough to believe that the problem is not yet completely solved, no apologies are offered. This paper deals with an experiment performed on a large commercial scale under regular operating conditions, which is a follow-up of results obtained on initial small-scale laboratory tests and port slag tests. The service results obtained indicate the beneficial results of proper mineralogical brick constitution in the "as received" condition.

The present experiment was conducted in a furnace melting a regular soda-lime-flint bottle batch. The furnace was a six-port side regenerative type with a melter area of 953 square feet. It was fired with natural gas. This is quite important to remember as identical results would probably not be observed with another type of batch or fuel, even in the same furnace.

II. Mineralogical Composition

It is not the purpose of the present paper to discuss the various methods and degrees of accuracy of determining the actual mineralogical composition of super-duty or high alumina brick, so only brief reference will be made to some of the methods used.

The X-ray method is not entirely satisfactory as it does not indicate the size, orientation, and manner of grouping of the mullite crystals. It also entails a piece of expensive equipment and a trained operator. For further information on this method, the reader is referred to the work of Riddle,[1] Navias,[2] Navias and Davey,[3] Nahmias,[4] Posnjak and Greig,[5] Norton,[6] Bragg, Shearer, and Mellor,[7] Hyslop,[8] Shearer,[9] Rinne,[10] and Westman.[11]

Digestion by acids sometimes affects the matrix, and mullite crystals themselves are somewhat soluble in some of the acids used. The work of Rees,[12] McVay,[13] and Rieke and Schade[14] illustrates some of the possibilities of this method. The work of Lu,[15] is an interesting and capable piece of work using a combination of chemical and microscopic methods to determine the mineralogical composition of fired clay.

Etching of the plane polished surfaces and examination by the microscope appears to give fairly satisfactory results under some conditions, but considerable technique and experience are needed.

---

* Presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 18, 1939 (Refractories Division). Received April 18, 1939.

[1] F. H. Riddle, "Effect of Preparation and Calcination Treatment on Properties of Kaolin-Alumina Mixtures $Al_2O_3 \cdot SiO_2$," *Jour. Amer. Ceram. Soc.*, **15** [11] 583–97 (1932).

[2] Louis Navias, "Quantitative Determination of Development of Mullite in Fired Clays by an X-Ray Method," *ibid.*, **8** [5] 296–302 (1925).

[3] Louis Navias and W. P. Davey, "Differentiation Between Mullite and Sillimanite by Their X-Ray Diffraction Patterns," *ibid.*, **8** [10] 640–47 (1925).

[4] M. E. Nahmias, "Second Symposium on Physical Chemistry of Alumina-Silica Refractories: III, Bauxites and Mullites," *ibid.*, **16** [9] 420–21 (1933).

[5] E. Posnjak and J. W. Greig, "X-Ray Diffraction Patterns of Mullite," *ibid.*, **16** [11] 569–83 (1933).

[6] J. T. Norton, "X-Ray Study of Cyanite and Andalusite," *ibid.*, **8** [10] 636–39 (1925).

[7] W. Bragg, G. Shearer, and J. W. Mellor, "Crystalline Structure of Some China Clays Examined by the X-Ray Powder Method," *Trans. Ceram. Soc.* [England], **22** [1] 105–10 (1922); *Ceram. Abs.*, **3** [1] 24 (1924).

[8] J. F. Hyslop, "Constitutional Changes Occurring in Clays on Heating," *Trans. Ceram. Soc.* [England], **24**, 402–406 (1924–25).

[9] G. Shearer, "Results of an X-Ray Investigation of the Crystalline Nature of China Clays," *ibid.*, **23**, 314–17 (1923–24); *Ceram. Abs.*, **4** [10] 288 (1925).

[10] F. Rinne, "Use of the X-Ray in Ceramics," *Keram. Rundschau*, **33**, 427–29, 459–60, 525–27 (1925); *Ceram. Abs.*, **5** [5] 166 (1926).

[11] A. E. R. Westman, "X-Ray Study of Fire Brick," *Univ. of Ill. Eng. Expt. Sta. Bull.*, No. 193, 16 pp. (1929); *Ceram. Abs.*, **9** [6] 430 (1930).

[12] W. J. Rees, "Alumina-Silica Minerals in Fire Brick," *Trans. Ceram. Soc.* [England], **24** [1] 23–26 (1925); *Ceram. Abs.*, **4** [11] 310 (1925).

[13] T. N. McVay, "Determination of Mullite in a Porcelain Body," *Jour. Amer. Ceram. Soc.*, **10** [1] 62–63 (1927).

[14] R. Rieke and W. Schade, "Determination of Mullite Content in Porcelain by Chemical Means and Relation Between Determined Mullite Content and Properties of Porcelain," *Ber. deut. keram. Ges.*, **11** [8] 427 (1930); *Ceram. Abs.*, **10** [5] 363 (1931).

[15] Kai-Ching Lu, "Glass Tank Refractories and Their Chemical Relationship to Molten Glass," *Ohio State Univ. Eng. Expt. Sta. Bull.*, No. 44 (1928); *Ceram. Abs.*, **8** [3] 194 (1929).

The petrographic microscope is still one of the best tools for brick study. It is not easy to use it to determine the mineralogical content of super-duty firebrick that have not been highly fired. With super-duty firebrick, however, that have been fired to cone 17 down, the presence of mullite crystals can readily be detected. An examination of both thin and powder sections coupled with other general knowledge of the physical and chemical properties of the brick gives a fairly correct estimate of the degree of formation of mullite.

In making the comparison between the two brick brands being reported on in this paper, great care was taken to secure brands as nearly alike as possible in chemical composition, grain size, and physical properties. The chemical and physical properties of the two brands, to be referred to as brands A and B, are given in Table I.

TABLE I

Brand	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Alkali
A	52.0	43.4	1.50	1.95	0.30	0.27	0.50
B	53.1	42.2	1.30	1.90	0.50	0.3	0.60
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A	11.0	34	−0.3	2.32	1200	1.2	1.9
B	11.5	33	+0.1	2.30	1100	0.9	1.2

Column (1) porosity (%), (2) P.C.E., (3) A.S.T.M. preheat 2552°F, (4) bulk sp. gr., (5) modulus of rupture (lb./sq. in.), (6) A.S.T.M. panel spalling test (% loss), (7) A.S.T.M. hot load test, 25 lb./sq. in. at 2642°F (% deformation).

Although these two brands are not identical in chemical and physical properties, they are similar. Possibly the greatest obstacle to an intelligent comparison between these two brands was a difference in the grain size and texture. In spite of the care taken in trying to get brands as nearly alike in this respect as possible some difference did exist, although they both are of the same general type and were manufactured for the same type of service. The texture of brands A and B is shown in Figs. 1, 2, and 3. It may be noted that brand A appears to be much freer of tiny voids than brand B.

An interesting comparison may be made of the actual mineralogical content of brand A with that which would theoretically be attained if the brick were an intimate mixture and fired to complete equilibrium conditions.

It is realized that other oxides, such as MgO, Na_2O, Fe_2O_3, K_2O, and B_2O_3, are fully as effective as CaO in acting as a flux. As there is no ternary diagram, however, consisting of "fluxes–SiO_2–Al_2O_3," the CaO–SiO_2–Al_2O_3 diagram was chosen in this particular instance. Assuming therefore that the composite general effect of the fluxes in these particular super-duty fireclay brick compositions would promote the same general trend of crystallization that is found in the CaO–SiO_2–Al_2O_3 diagram, this diagram is used as an illustration. Using these three components, the composition of most super-duty brick of the type being discussed would fall within the dotted circle of Fig. 4. Let point *B* represent an average composition. In cooling a melt with the composition of point *B*, the primary phase mullite would crystallize out from B along the line *BC* to point *C*. At point *C*, silica starts to crystallize out along with mullite. The gross composition of the crystals coming out at *C* is represented by a tangent to the boundary, *FO*, at point *C* and cutting the line SiO_2–Al_2O_3 at approximately point *O*. Crystallization of silica and mullite continues to point *F* where final crystallization takes place. The final composition is represented by the following line segment relations:

$\frac{FB}{FT} \times 100 = 84.5\%$ crystalline materials of both silica and mullite.

$\frac{BT}{FT} \times 100 = 15.5\%$ glassy material of composition *F*.

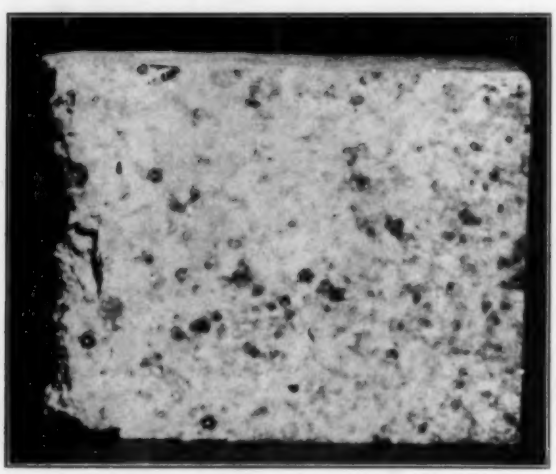

FIG. 1.—Cross section, brand A.

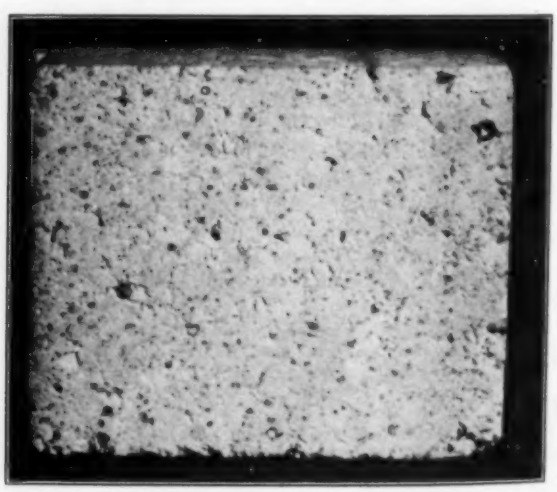

FIG. 2.—Cross section, brand B.

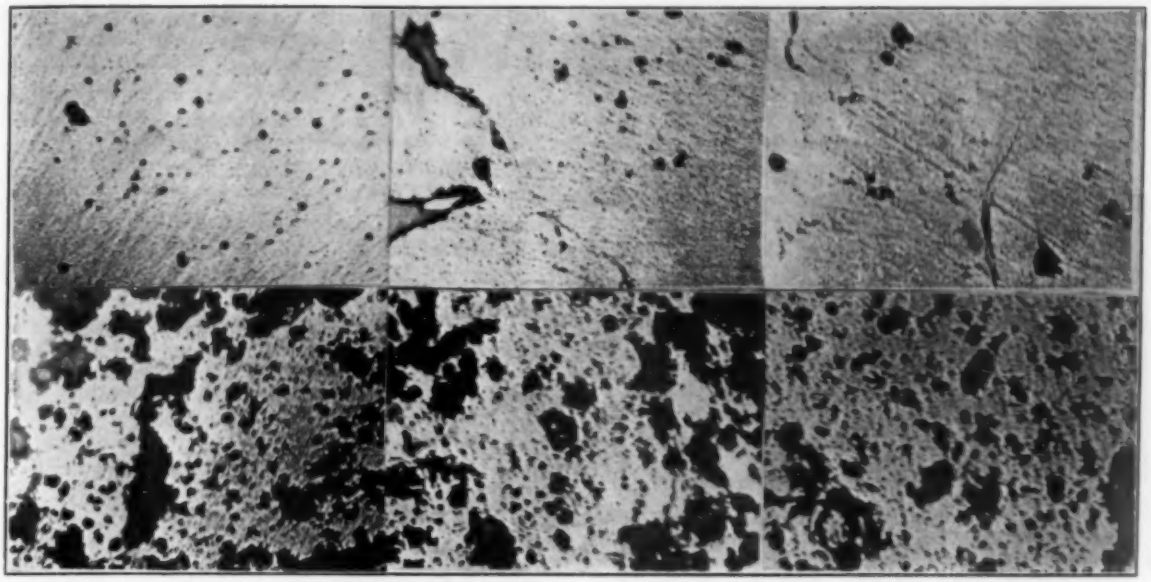

FIG. 3.—Photomicrographs; natural light, magnification 100×; top row, brand A; lower, brand B.

$\frac{LT}{LH} \times 100 = 62.5\%$ of $84.5\% = 52.8\%$ mullite.

$\frac{TH}{LH} \times 100 = 37.5\%$ of $84.5\% = 31.7\%$ crystalline silica as cristobalite and tridymite.

What was actually secured on brand A is shown in Fig. 5. It represents nearly 40% of well-developed mullite crystals and ample evidences of more mullite crystals in the incipient stage. The mullite crystals are dispersed throughout the rather glassy matrix and around the borders of the larger clay grains. The remainder of the material shows up as unconverted, vitreous, hard clay material with some quartz grains dispersed throughout. There are some evidences of cristobalite, part of which may have been due to conversion of the quartz grains and part due to crystallization from siliceous glass.

A thin section of brand B (Fig. 6) shows that there are few microscopically visible mullite crystals present. Both brands may theoretically form about the same percentage of mullite. There are indications that the manufacturer of brand A did a good job of securing mullite crystals that were large enough to identify petrographically; this is not true of brand "B."

III. Service Conditions and Results

Port slag tests run on brands A and B showed a consistent volume loss 6% greater on brand B than on brand A. To check the validity of these test results, the experiment was carried on under actual operating conditions of a large-size commercial operation. Several thousand 9-inch brick of brand A were placed in the top checkers of one regenerator of the furnace and an equal number of brand B were placed in the same position in the other regenerator of this furnace. The furnace was heated up and went into production. After four months, the checker tops of both the regenerators were opened, inspected, and samples drawn from the top course of each side. Outwardly, the brick appeared to be the same, being of equal dimensions and the same color. When the samples were broken in half, brand B showed a very thick penetration or

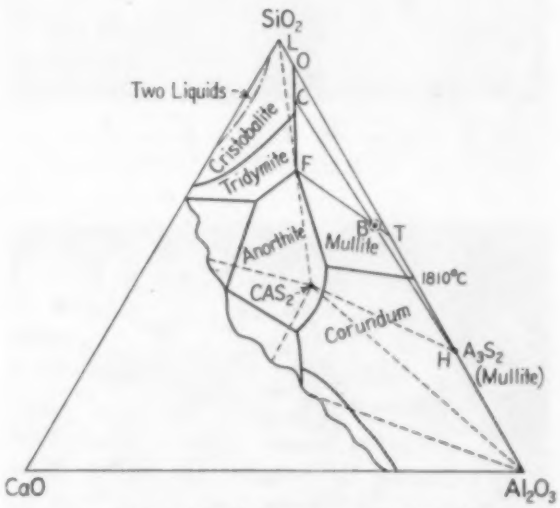

FIG. 4.—Adaptation of ternary system CaO–Al_2O_3–SiO_2 (G. A. Rankin and F. E. Wright and modified by N. L. Bowen and J. W. Greig); for complete and original system diagram, see *Jour. Amer. Ceram. Soc.*, **16** [10] 524 (1933).

transition layer of alkalis. The alkali vapors apparently had reacted with this brick to a depth of one-half inch, surrounding an unaltered core of brick. Brand A did not show this thick layer of alkaline reaction, but presented only a very thin skin of penetration (Fig. 7). The furnace continued operation until it was ten months old. At that time the brand B checkers had softened and sloughed off so badly that it was necessary to remove and replace most of them. The brand A checkers were in good condition although they showed the usual wear for such a period of service. At the end of $15^1/_2$ months, it was necessary to shut down the furnace for business reasons, and the brand A checkers were still in excellent condition and functioning perfectly (see Fig. 8).

A cross section of one of the brick is shown in Fig. 9. The lack of any deep alkali penetration is quite noticeable. (No picture was obtained of brand B because it had been replaced.) The outer crust or penetration layer on brand B is analyzed chemically (see Table II).

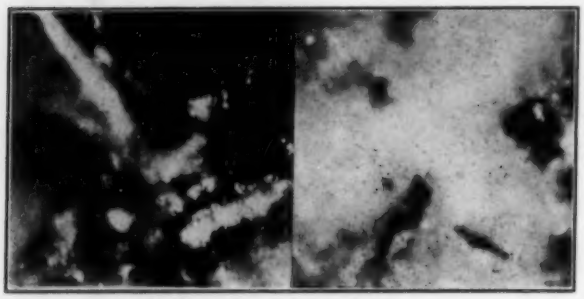

FIG. 5 (*left*).—Unused brick, brand A; crossed Nicols, magnification 350×; showing visible mullite formation in brick in the "as received" condition.

FIG. 6 (*right*).—Unused brick, brand B; crossed Nicols, magnification 350×; showing lack of visible mullite formation in brick in the "as received" condition.

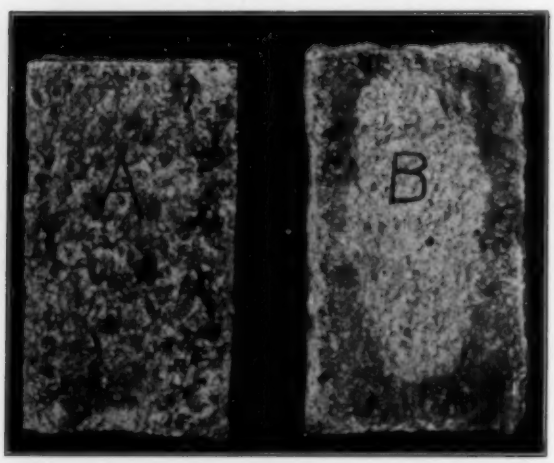

FIG. 7.—Half sections of brands A and B after four months in service; deeper reaction of alkalis on brand B may be noted.

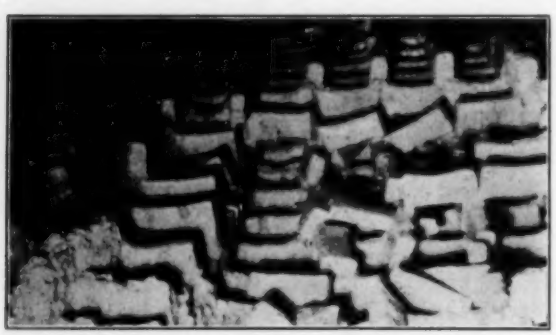

FIG. 8.—View of brand A brick still in place in regenerator after continuous service of $15^1/_2$ months.

TABLE II

CHEMICAL ANALYSIS OF OUTER CRUST OF BRAND B

	(%)		(%)
SiO_2	46.75	BaO	0.26
Al_2O_3	32.00	TiO_2	2.13
Fe_2O_3	3.80	SO_3	0.98
CaO	0.48	Ignition loss	0.12
Na_2O	13.03		

A thin section of this material was studied (Fig. 10) under the petrographic microscope and about the same

FIG. 9.—Cross section of used brand A brick taken from top checkers after $15^1/_2$ months of service; the absence of deep alkali penetration is noticeable.

products were present as those found by Thompson and Rexford,[16] Insley,[17] and other investigators. The outer layer next to the glass was nephelite ($Na_2O \cdot Al_2O_3 \cdot 2SiO_2$) merging into the clay material with some small mullite crystals present. Apparently the checker temperature was sufficiently low so that the viscosity of the slag allowed it to stay in place long enough for nephelite to form in place. In some checkers, the temperature is high enough that the slag runs away as fast as it is formed with little chance for nephelite to form.

Figure 11 shows the thermal expansion before and after use of both brands. In both cases, the expansion of the used brick was slightly lower than that of the new brick. This probably indicates that mullite formation was completed with some of the crystalline silica present going over to a siliceous glass. This is particularly true in the case of brand B. The transition layer of B showed quite a high expansion, which would be expected in view of its previously discussed mineralogical composition.

FIG. 10.—Transition or outer layer of used brand B; crossed Nicols, magnification 350×; showing nephelite as white areas. Nephelite is separated from solid portion of brick by varying amounts of mullite crystals so small as to be almost indistinguishable.

IV. Conclusions

It was concluded from this work that brand A was definitely superior to brand B. One of the outstanding differences between these brands was the much higher content of microscopically visible mullite in brand A in the "as received" condition. Harvey and Birch[18] proved that there was as much mullite present

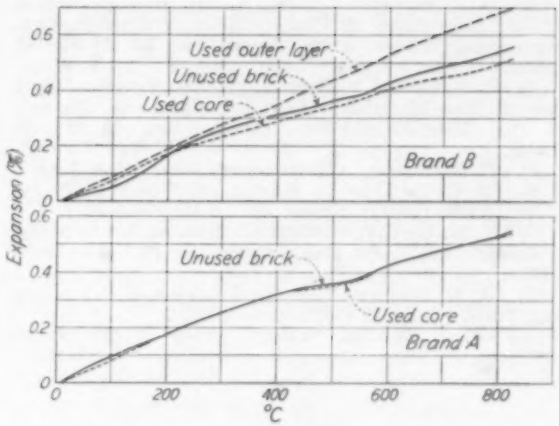

FIG. 11.—Reversible thermal expansion of brands A and B.

in a super-duty fireclay brick fired to cone 11 as there was in one fired to cone 18 but that the mullite crystals in the cone 18 run were larger. This leads to the conclusion that under any conditions of service where brand B would have been exposed to high heat without a severe chemical attack starting at once its mullite crystals would have eventually grown or coalesced until they would have been similar to brand A. Apparently in the present condition of service, the chemical attack of the alkali had formed quite a thick transition layer, and whatever additional growing the mullite already present in B could do under these service conditions was insufficient to prevent the failure of the brick. The transition layer formed was viscous enough to remain in place for a while, but upon continued dilution by alkali it sloughed off causing failure.

It should be remembered, however, that simply a high degree of mullitization in a fire brick will not insure its resistance to slag attack. The other physical properties of the brick also have to be correct.

All of the causes or methods of securing high mullite must be taken into consideration. Perhaps a brick may develop a high percentage of mullite quite readily owing to a considerable amount of fluxing agents in the groundmass of the brick. This means that the glassy phase in which the mullite is formed probably would not be refractory enough for some service conditions. It is also possible to have a brick mix so refractory that it is difficult to produce a satisfactory mullite content and the bond between grog and matrix might be too dry for good results.

OWENS-ILLINOIS GLASS COMPANY
ALTON, ILLINOIS

Bibliography

(1) C. E. Grigsby, "Effect of Typical Slags on Fire Brick with Method of Determination Correlated to Service," *Jour. Amer. Ceram. Soc.*, **12** [4] 241–63 (1929).

(2) L. R. Faulkner, "Slagging Action of Fuel-Oil Ash," *Bull. Amer. Ceram. Soc.*, **13** [2] 45–46 (1934).

(3) F. S. Thompson and H. M. Kraner, "Refractories for Manufacture of Glass," *Ind. Eng. Chem.*, **25** [8] 856–64 (1933); *Ceram. Abs.*, **12** [10–11] 374 (1933).

(4) S. J. McDowell and H. C. Lee, "Petrographic Study of Some Slags from Boiler Furnaces," *Jour. Amer. Ceram. Soc.*, **11** [1] 35–41 (1928).

[16] C. L. Thompson and E. P. Rexford, "Study of an Alumina-Silica Checker Brick from the Regenerator of a Glass Tank," *Jour. Amer. Ceram. Soc.*, **21** [2] 55–59 (1938).

[17] Herbert Insley, "Behavior of Refractories in Glass Melting Furnaces," *ibid.*, **7** [8] 583–93 (1924).

[18] F. A. Harvey and R. E. Birch, "Mullite Development in Super-Duty Fireclay Brick," *ibid.*, **19** [11] 322–27 (1936).

(5) D. S. Beliankin and M. A. Besborodov, "Action of Dust from Batch on Checker Brick of Glass-Furnace Regenerators," *Jour. Amer. Ceram. Soc.*, **13** [5] 346–53 (1930).
(6) T. Nakai and Y. Fukami, "X-Ray Examination of Ceramic Raw Materials," *Jour. Soc. Chem. Ind.* [Japan], **36** [10] 559–62B (1933); *Ceram. Abs.*, **13** [2] 47 (1934).
(7) F. Hartmann, "Quantitative Estimation of Attack of Slag and Flue Dust on Refractories," *Stahl u. Eisen*, **47** [5] 182–86 (1927); *Ceram. Abs.*, **6** [5] 178 (1927).
(8) T. N. McVay, "Optical Methods as Aid to Study of Refractories," *Jour. Amer. Ceram. Soc.*, **12** [7] 455–56 (1929).
(9) H. E. Simpson, "Classified Review of Refractory Slag Tests," *ibid.*, **15** [10] 536–44 (1932).
(10) F. H. Norton, "Critical Study of Differential Thermal Method for Identification of Clay Minerals," *ibid.*, **22** [2] 54–63 (1939).
(11) Anon., "Checker-Brick Performance," *Glass Ind.*, **17** [10] 349–52 (1936).
(12) D. W. Ross, "Regenerative Furnace Refractories," *ibid.*, **18** [7] 241–43 (1937); *Ceram. Abs.*, **17** [5] 187 (1938).
(13) H. Jebsen-Marwedel, "Slagging of Glass Tank Refractories Above the Metal Line," *Glastech. Ber.*, **15** [4] 131–36 (1937); translated in *Glass Ind.*, **18** [9] 304–306 (1937); *Ceram. Abs.*, **17** [5] 176 (1938).
(14) Anon., "Checker Brick for Regenerators," *Glass Ind.*, **15** [11] 281–82 (1934).
(15) H. M. Kraner, "Some Considerations in the Production of Fused Mullite for Refractories," *Jour. Amer. Ceram. Soc.*, **21** [10] 360–66 (1938).
(16) R. B. McCormick, "Advanced and Refined Technique in Petrographic Study of Crystalline Refractories," *ibid.*, **19** [1] 7–13 (1936).

THERMOCHEMISTRY OF NORTH CAROLINA OLIVINE IN THE MANUFACTURE OF FORSTERITE REFRACTORIES*

By Robert L. Stone

Abstract

A review of the properties of forsterite refractories is presented, and the causes of their failure are discussed. The main cause of failure is incomplete conversion of the impurities as shown by photomicrographs. The figures also show the several stages of breakdown of the crude olivine and the stages of conversion to forsterite as dependent upon temperature. The relation of the thermochemistry of the olivine to the manufacture of high-grade forsterite refractories is given.

I. Introduction

Forsterite refractory brick are made in the United States by firing mixtures made from a carefully selected dunite rock to which MgO in the form of raw or calcined magnesite has been added. Approximately the same process is in use in Norway, but in Germany magnesium oxide is added to talc or steatite. The magnesium, iron, and olivine from which these refractories are made is essentially a solid solution of fayalite (Fe_2SiO_4) in forsterite (Mg_2SiO_4).

No one has yet given a clear picture of what occurs upon heating raw olivine or a mixture of magnesium oxide and olivine to temperatures up to 3000°F although several studies of olivine have been made.[1]

In the present study, the writer explains the chemical behavior of olivine during the production of forsterite refractories.

II. Mining and Purification of Olivine

The rock samples used were hand-picked from medium olive-green material from Balsam Gap, N. C., and they contained very little antigorite, talc, and chlorite. The impurities present were formed in the rock mass during the first stage of metamorphism and by subsequent normal weathering.[2] The olivine contained approximately 10% fayalite in solid solution.[3]

The analysis of the material was SiO_2 40.1, Al_2O_3 1.0, Fe_2O_3 6.7, CaO 0.2, MgO 50.5, and alkalis 1.7%, a total of 100.2%.

* Presented at the Fortieth Annual Meeting, American Ceramic Society, New Orleans, La., March 30, 1938 (Refractories Division). Received March 31, 1938; revised copy received February 10, 1939.

[1] (*a*) R. A. Heindl and W. L. Pendergast, "Olivine as a Refractory," *Bur. Stand. Jour. Research*, **12** [2] 215–22 (1934); R.P. 645; *Ceram. Abs.*, **13** [5] 119 (1934).
(*b*) Gunnar Knudsen, V. M. Goldschmidt, and Rolf Knudsen, Brit. Pat. 301,547, June 4, 1928.
(*c*) F. A. Harvey and R. E. Birch, "Refractories," U. S. Pat. 2,077,795, April 20, 1937; *Ceram. Abs.*, **16** [7] 209 (1937).
(*d*) R. E. Birch and F. A. Harvey, "Forsterite and Other Magnesium Silicates as Refractories," *Jour. Amer. Ceram. Soc.*, **18** [6] 176–92 (1935); p. 187.
(*e*) V. M. Goldschmidt, "Olivine and Forsterite Refractories in Europe," *Ind. Eng. Chem.*, **30** [1] 32–34 (1938); *Ceram. Abs.*, **17** [10] 331 (1938).
(*f*) See also Fig. 7.

[2] (*a*) J. L. Stuckey and R. L. Stone, "Geology of the Dunite Mass at Balsam, N. C." (in preparation).
(*b*) A. F. Greaves-Walker and R. L. Stone, "Production of Unfired and Fired Forsterite Refractories from North Carolina Dunites," *N. C. State Coll. Eng. Expt. Sta. Bull.*, No. 16, 122 pp. (Sept., 1938); Raleigh, N. C.

[3] The amount of fayalite was determined by the indices of refraction; the indices are appreciably higher for fayalite than for forsterite.

III. Method of Investigation

The two phases of this investigation were (1) a study of the reactions taking place in lumps and chips of raw olivine rock when heated and (2) a study of a mixture of olivine and a conversion agent.[4]

(1) Preparation of Crude Olivine Samples

Lumps of olivine, representative of an average carload shipment, were broken with a hammer into chips approximately 1 inch square by 1/4 inch thick. These samples hereafter are referred to as "olivine chips."

An optimum temperature of firing crude olivine was determined by firing the chips. A number of lumps of olivine (3 to 4 inches in diameter) were selected as average of a shipment to be fired to the optimum temperature.

(2) Preparation of the Olivine-Conversion Agent Mixture

The olivine was reduced in a jaw crusher to pass a 3-mesh screen, and the conversion agent was ball-milled to pass 40-mesh. A batch consisting of 80% crude olivine[5] and 20% conversion agent was dry-mixed; 5% water was added. Specimens, 2 1/2 inches in diameter and 1 inch thick, were pressed at 5000 lb. per sq. in. These specimens were dried at 230°F before firing.

This particular mix was chosen to obtain information on (1) the effect of grain size on oxidation and precipitation of iron compounds at the grain boundaries and (2) the reactions resulting from the presence of the conversion agent.

These specimens will be termed "briquettes" to distinguish them from the 9-inch straights, the olivine chips, and lumps.

(3) Firing of Samples

The specimens were fired at the rate of 300°F per hour to 900°F and then at 100°F per hour to the end of the test. The firing was done in a gas-fired downdraft kiln in an atmosphere oxidizing to FeO.

Temperatures were measured with a standardized Pt Pt-Rh couple.

Olivine chips were drawn from the kiln at 900°, 1000°, 1100°, 1250°, 1300°, 1400°, 1500°, 1600°, 1700°, 1800°, 1880°, 2010°, 2150°, 2280°, 2360°, 2430°, 2600°, and 2720°F. Specimens of the dry-pressed briquettes were drawn at 2500°, 2600°, 2700°, 2800°, and 2900°F.

When the samples were drawn they were placed on a cold steel plate to arrest the chemical reaction. All chips had fused at 2800°F, and the briquettes, intended for 3000°F, had slagged through the kiln floor (high alumina brick) at 2950°F. Full-size brick containing the conversion agent fired to 3000°F (cone 30 down) were used in the microscopic examination.

No soaking period was allowed because phase equilibrium in the olivine mass does not appreciably lag behind a rapid temperature rise until a temperature of 2850°F or higher has been reached.

(4) Microscopic Examination

All specimens (briquettes and chips) were studied petrographically by the fragment and thin-section methods. Particular precaution was taken to grind all thin sections to exactly 0.03 mm. thickness.[6]

By placing a sheet of white paper under the stage of the microscope and directing the light from a microscope lamp on the thin section at a 30° angle from the horizontal, an indication of all the phases present could be obtained. The transmitted light showed the grain outline and the incident light showed the surface characteristics.

IV. Results of the Investigation

Microscopic observations are given in the results, but there were no X-ray examinations or chemical analyses.

(1) Breakdown of Olivine in Absence of Conversion Agent

Durbin[7] stated that olivine alters easily upon exposure to normal weathering. The olivine or dunite at Balsam is normally dense, but it soon becomes sugary if it is exposed to the weather. The color does not change appreciably until after several months of exposure.

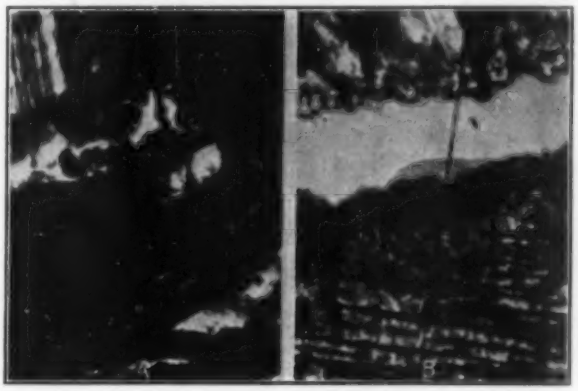

FIG. 1.—(*A*) Section from olivine chip fired to 1300°F; iron is precipitated in the 010 cleavage plane (upper left corner) and in the 100 parting plane (lower right corner); the black section is dark red under the microscope; polarized light, ×240.

(*B*) Section from olivine chip fired to 2450°F; iron oxide has agglomerated more than in (*A*) and is probably Fe_3O_4, but it has not migrated to centers; polarized light, ×240.

[4] The conversion agent employed was a partially calcined magnesitic dolomite with a MgO to CaO ratio of approximately 3 to 1.

[5] The crude olivine had a grain-size composition of 14% minus 3- + 6-mesh, 31% minus 6- + 20-mesh, and 41% minus 20-mesh (Tyler standard sieve sizes).

[6] Forsterite has interference colors of the lower second order and upper first order in sections of proper thickness.

[7] E. A. Durbin, "Manufacture of Olivine Refractories," *Brick Clay Rec.*, **87** [1] 21 (1935); *Ceram. Abs.*, **14** [10] 249 (1935).

The state of the iron oxides in the temperature ranges given in Table I are shown in Figs. 1 to 3, inclusive.

TABLE I

COLOR CHANGES IN OLIVINE DURING HEATING

Temperature (°F)	Color	Reason for color
70–1250	Olive green to moss green	Oxidation of the iron as Fe_2O_3 from the fayalite at the grain boundaries
1250–1300	Change from moss green to reddish brown	Complete breakdown of the fayalite to precipitate Fe_2O_3 in cleavage planes and on the grain surfaces
1300–2100	Reddish brown to brownish black	Gradual agglomeration of the Fe_2O_3
2100–2700	Brownish black to grayish black	Change from Fe_2O_3 to Fe_3O_4 and migration of Fe_3O_4 to grain boundaries
2700+	Black to very dark green	Formation of a high iron glass around forsterite grains

The breakdown of Fe_2O_3 to Fe_3O_4 continues, and the molecules of Fe_3O_4 migrate short distances to form tiny crystals in the cleavage planes and on grain boundaries of the forsteritic material. The mode of existence of the Fe_3O_4 at this stage is shown in Figs. 1(*B*), 2(*A*), and 2(*B*). The loss of oxygen has slowed considerably at approximately 2500°F (1372°C), and a mass movement of the Fe_3O_4 to the grain boundaries begins.

At 2700°F, the iron oxide has almost completely migrated to the grain boundaries and has formed flakes and nodules of appreciable size (shown by the black areas in Fig. 3(*A*)). No traces were found of a liquid phase caused by any oxide of iron at temperatures up to 2700°F. At 2700°F and above, FeO will form a very fluid magnesia-ferrous iron-silica slag. No slag will form as long as an atmosphere strongly oxidizing to FeO is maintained.

Considerable recrystallization of the forsteritic material has taken place at 2700°F as shown by Fig. 3(*B*). This material may appear as single crystals under transmitted or reflected light, but under crossed Nicols there will be a mass of crystals with different optical orientation. This is particularly true in areas where the iron oxide has centered.

(2) Decomposition Components of the Fayalite

Fayalite decomposes, liberating one molecule of silica for each molecule of fayalite.[1(a)] No trace of any silica mineral has been found in more than thirty thin sections examined. The silica would be liberated as α-quartz up to 575°C and as β-quartz from 575° to 870°C (1067° to 1598°F). The oxidation of the fayalite is complete at 705°C (1300°F) or within the β-quartz range. This silica mineral should appear as tiny gray specks under crossed Nicols. The silica apparently remains within the forsteritic material in molecular size or close to molecular size, and the iron oxide migrates to the grain boundaries.

The olivine rock contains approximately 8% of impurities, which are present as separate mineral grains, and may be distinguished from fayalite, which is in solid solution. These grains of impurities are so coarse that they have little effect on the melting of the forsterite, *i.e.*, the mass is not homogeneous. The lightest colored oval areas in Fig. 5 are the result of melting these grains. Because they are not evenly dispersed in the forsterite material as is the silica from the fayalite, they do not act in the same manner. The liquid formed by melting the impurities will react with the adjacent surface of the forsteritic material, which causes the globular or oval shape of these white areas.

Several chromite grains in the thin sections of the fired olivine are embedded in a film of glass which results from the chlorite that surrounds them. The absence or presence of free oxygen in the kiln atmosphere does not affect the melting of the antigorite, talc, and chlorite. The glass resulting from the melting of these impurities does not migrate as does the iron oxide.

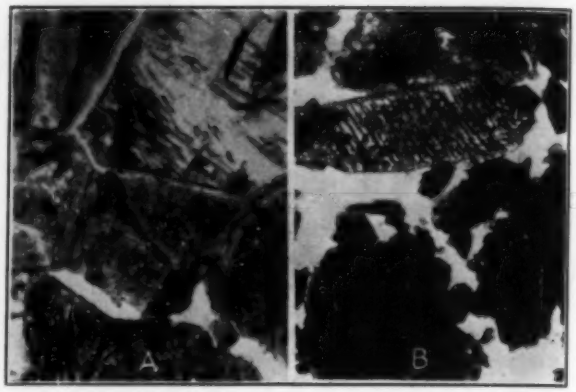

FIG. 2.—(*A*) Section from olivine chip fired to 2450°F, taken under incident light; the iron is in the same state as in Fig. 1(*B*); iron oxide is either cubes of Fe_3O_4 or Fe_2O_3; incident light, ×80.

(*B*) Section from raw olivine brick (20-mesh olivine) fired to 2500°F; iron oxide is in the same state as in (*A*) but is more oxidized owing to the grinding; polarized light, ×80.

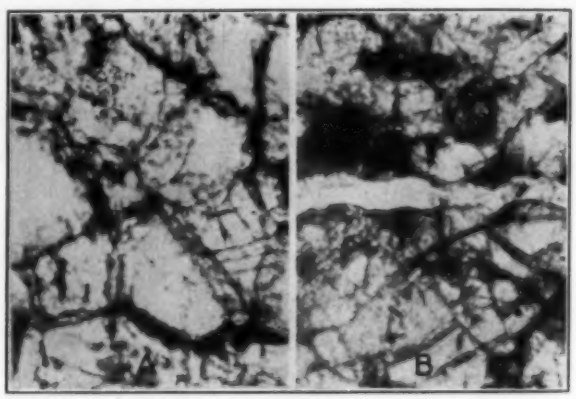

FIG. 3.—(*A*) Section from olivine chip fired to 2720°F; iron oxide (black) has migrated to grain boundaries of forsterite (white); polarized light, ×80.

(*B*) Section from olivine chip fired to 2720°F shows recrystallization; black areas chiefly partially recrystallized areas of different optical orientation; crossed Nicols, ×80.

The center of interest in this discussion is the condition within the olivine crystals themselves rather than in the composite rock. If the olivine contained 10% fayalite and 90% forsterite, the analysis would be 41.34 % SiO_2, 7.06% Fe_2O_3, and 51.60% MgO. Because the hematite and magnetite actually act as separate systems from the forsteritic material at 2700°F,[8] forsteritic material would have a composition of 44.5% SiO_2 and 55.5% MgO. If the silica from the fayalite is evenly dispersed in the forsteritic material, the mixture will behave according to the MgO–SiO_2 system. The first appearance of liquid[9] will be at 1557°C (2834.6°F) (Fig. 7). This liquid will appear within the crystal of forsteritic material and therefore will be damaging.

[8] The iron oxides have agglomerated, leaving the forsteritic material behind, and therefore can not be in equilibrium with the forsteritic material.

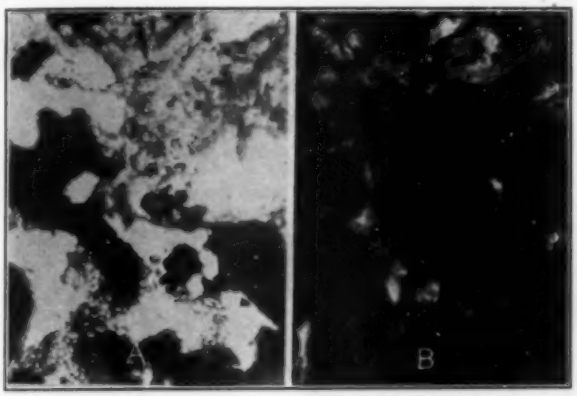

FIG. 4.—(*A*) Section from briquette of the composition 80% olivine −3-mesh, 20% conversion agent −40-mesh, fired to 2600°F; tiny globules in lower left corner are periclase from conversion agent; some MgO has reacted to form magnesio-ferrite (black); polarized light, ×80.

(*B*) Section from briquette of same composition as (*A*) fired to 2800°F; black globules (reddish brown under the microscope in lower left corner are MgO; light areas in and around the black are recrystallized or secondary forsterite; polarized light, ×360.

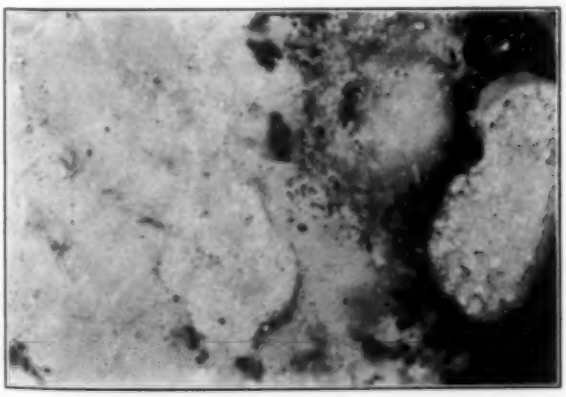

FIG. 5.—Section from briquette of same composition as Fig. 4 but fired to 2900°F; taken under incident light; black specks are chiefly Fe_3O_4 and globular black areas are magnesio-ferrite; oblong spotted white areas are cristobalite and enstatite resulting from recrystallization of melted talc; the large forsterite grain (left) is free of iron compounds; incident light, ×80.

(3) Effect of Incorporating MgO

The magnesium oxide is being incorporated with crushed olivine in the manufacture of forsterite refractories in order to form secondary forsterite with silica from the fayalite and with the decomposition products of antigorite, talc, and chlorite and also to form magnesio-ferrite with the iron oxide from the fayalite. The silica from the fayalite, however, does not enter into these reactions because it is not at the grain boundaries where magnesium oxide is available. The iron oxide

[9] The isopleth of 44.5% SiO_2 will intersect the solidus line (Fig. 7).

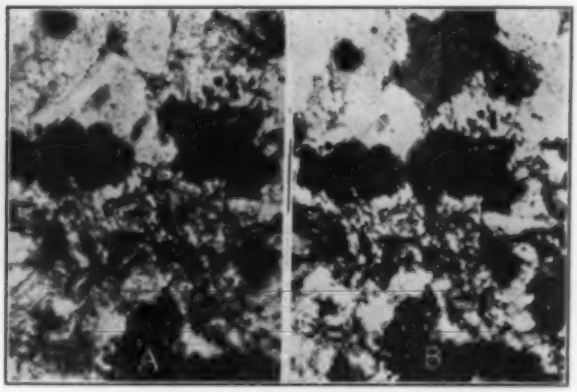

FIG. 6.—(*A*) Section from briquette of same composition as Fig. 4, but fired to 2900°F; tiny dark globules spots are periclase from conversion agent; much more magnesio-ferrite than in Fig. 4; polarized light, ×80.

(*B*) Composition of briquette and firing temperature same as in (*A*); crossed Nicols to show recrystallization; crossed Nicols, ×80.

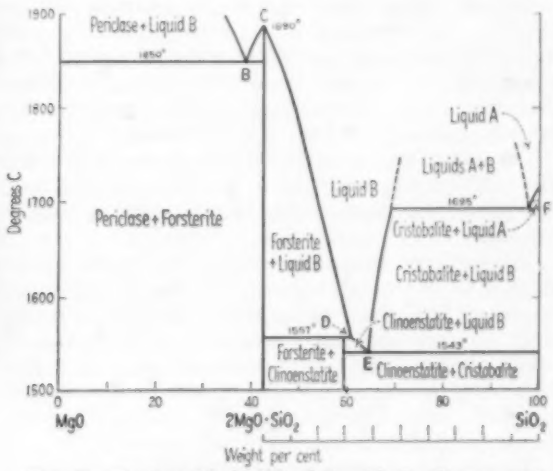

FIG. 7.—System MgO–SiO_2 (after N. L. Bowen and O. Andersen), *Amer. Jour. Sci.*, 4th Ser., **37**, 487–500 (1914).

and the silica from the impurities, however, do react. When 4% MgO is incorporated with the olivine it is sufficient to eliminate firing shrinkage. The theoretical amount of magnesium oxide (calculated from the chemical analysis of the olivine) necessary to react with the silica from the fayalite, talc, etc., and with the iron oxide from the fayalite was found to be approximately 12%.

The chemical reactions involved are as follows:

Antigorite

$$Mg_3Si_2O_9H_4 + \text{heat} \rightarrow Mg_2SiO_4 + MgSiO_3 + 2H_2O. \quad (1)$$
$$MgSiO_3 + MgO \rightarrow Mg_2SiO_4. \quad (2)$$

Talc

$$Mg_3Si_4O_{12}H_2 + \text{heat} \rightarrow 3MgSiO_3 + SiO_2 + H_2O. \quad (3)$$
$$MgSiO_3 + MgO \rightarrow Mg_2SiO_4. \quad (4)$$
$$SiO_2 + 2MgO \rightarrow Mg_2SiO_4. \quad (5)$$

The reactions with magnesium oxide to form secondary forsterite from clinoenstatite and silica usually do not occur so simply. In the decomposition of antigorite, forsterite and a liquid are formed at 1557°C (2835°F). The liquid, which is essentially a magnesia-silica phase, reacts simultaneously in the presence of sufficient magnesium oxide to bring the mean composition of the mass to 57.4% MgO and 42.6% SiO_2 and to form solid forsterite. Clinoenstatite and a liquid are formed from talc at 1543°C (2809°F), and the same reactions take place as with antigorite.

As the temperature is raised above 2900°F or is maintained for a considerable time at that temperature, the secondary forsterite crystals and the magnesioferrite crystals grow in size as shown in Figs. 8(*A*) and 9(*B*). These reactions will not be completed until sufficient time has been provided or until the necessary temperature has been reached.

(4) Temperature of Calcination and Refractory Stability

Very little reaction into which the magnesium oxide enters has taken place before 2700°F, and the reaction is not completed until approximately cone 30 (3000°F) is reached; *e.g.*, if calcination has been carried only to 2800°F, the formation of secondary forsterite and magnesioferrite is not complete. If a brick, therefore, is made of such a calcine, it will contain a glass phase that will again become fluid at high temperatures, causing slumping and peeling of the brick.

The melt of SiO_2 or MgO and SiO_2, formed within the grain of forsteritic material at 2834°F (1557°C), will not have been transformed into forsterite in such a calcine.

The calcining temperature should be carried above 2900°F in order (*a*) to complete the formation of secondary forsterite from the SiO_2 and $MgSiO_3$ of equations (1) and (3); (*b*) to complete the formation of magnesioferrite; (*c*) to form forsterite with the MgO–SiO_2 liquid arising from within the grains of forsteritic material; and (*d*) to permit the crystal growth of the magnesioferrite and secondary forsterite.

The reaction given in equation (6) will take place at a lower temperature in an atmosphere reducing to Fe_3O_4 than in a normal oxidizing atmosphere.

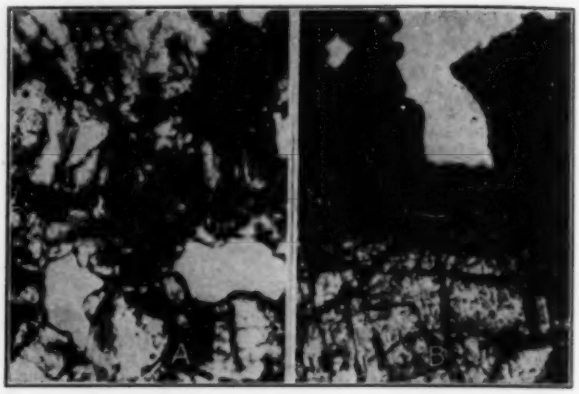

FIG. 8.—(*A*) Section from brick of calcine B (88.41% olivine −20-mesh, 11.59% conversion agent −40-mesh, fired to cone 30); shows absence of iron compounds within forsterite grains; polarized light, ×80.

(*B*) Section from brick of calcine *A** fired in load test to 2450°F; refiring has almost completely reoxidized iron compounds and redispersed them in forsterite grains; polarized light, ×80.

* Same composition as calcine B but calcined at 2900°F.

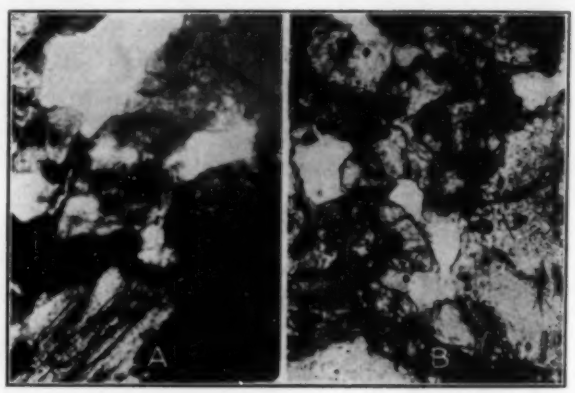

FIG. 9.—(*A*) Section from brick containing 50% calcine B (see Fig. 8(*A*)) and 50% raw olivine fired in load test to 2300°F); a large amount of iron oxide has been incorporated through raw olivine; polarized light, ×80.

(*B*) Section from commercial forsterite brick fired to cone 23; polarized light, ×80.

$$MgO + Fe_3O_4 \rightarrow MgFe_2O_4 + FeO. \quad (6)$$

The FeO of equation (6) must be oxidized to the ferro-ferric state (Fe_3O_4) to enter into the reaction, inasmuch as the oxide must be in the ferric state to form magnesioferrite. A series of alternately reducing and oxidizing conditions, therefore, will gradually reduce the iron oxide existing as such in the mass.

The ferric oxide cannot exist, as such, above 2700°F,[10] and the reaction to form $MgO \cdot Fe_2O_3$ will not occur appreciably below 2900°F. Each time conditions exist that are reducing to Fe_3O_4 at the stated temperature, the reaction in equation (6) goes to completion but the ferric part of the iron oxide only is removed. The remaining ferrous-iron part of the Fe_3O_4 ($FeO \cdot Fe_2O_3$)

[10] Hewitt Wilson, Ceramics–Clay Technology, 1st ed., p. 161. McGraw-Hill Book Co., Inc., New York, N. Y., 1927; *Ceram. Abs.*, **6** [11] 547 (1927).

must be oxidized to Fe_3O_4 as shown in equation (7).

$$6FeO + O_2 \rightarrow 2Fe_3O_4. \quad (7)$$

The reaction of equation (6) may then be repeated.

At higher temperatures (approximately 3000°F and above), the conversion of the iron oxide to magnesioferrite is complete in one step providing a normal atmosphere is maintained. Equation (8) shows this reaction.

$$6MgO + Fe_3O_4 + O_2 \rightarrow 6MgFe_2O_4. \quad (8)$$

Of course, the higher the temperature of calcination, the more complete will be the removal of the MgO–SiO_2 liquid phase within the forsteritic material.

(5) Effect of Too Low a Calcining or Firing Temperature

In case proper care is not taken to convert all of the iron into the stable magnesioferrite, it will exist as the oxide in the finished refractory. This iron oxide, upon subsequent heating, will be dispersed into the forsteritic material and will act as a powerful flux, especially if the Fe_2O_3 is reduced to the ferrous oxide. The brick from which the thin section shown in Fig. 8(*B*) was taken failed in the load test for this reason. The iron was not completely converted by the calcination process at 2900°F; upon being heated in the load test, the unconverted iron oxide was dispersed, causing the formation of a very fluid melt. A thin section of this calcine before being made into a brick appeared much like that in Fig. 8(*A*); upon refiring, the iron oxide was dispersed as shown in Fig. 8(*B*).

The calcination process was carried to 3000°F (cone 30 down), and this calcine was made into brick. These brick were also tested in the load-test furnace. The microscopic appearances of the calcine and the brick after test were identical, indicating that the stable magnesioferrite was not affected.

Brick made from the calcine A (2900°F) failed at 2400° to 2500°F when they were tested according to A.S.T.M. method C16–20; those made from calcine B (3000°F) did not fail until above 2550°F, even when loaded at 50 lb. per sq. in.

(6) Effect of Incorporating Crude Olivine in Forsterite Refractories

Brick were made of a mix containing 50% of calcine B (calcined at 3000°F) and 50% crude olivine, and they were tested before firing and after firing to 2700°F (cone 17). There was no difference in the behavior of the two under hot load; both failed at 2300° to 2350°F under a load of 25 lb. per sq. in.

The explanation of the failure may be seen in Fig. 9(*A*). The iron oxide from the crude olivine diffused throughout the mass, causing the formation of a liquid phase.

(7) Fine Grinding vs. Coarse Grinding

A granular mass of crushed olivine, passing a 3-mesh screen, and a 4-inch lump of raw olivine were placed in the kiln, fired to 2710°F, and held at that temperature for four hours to insure the absence of a temperature gradient in the lump.

The outside appearance of the two masses (crushed and lump) was the same. The lump was broken in half. The oxidation, or decomposition, of the fayalite had taken place to a depth of not more than $^3/_{16}$ inch. In other words, there was a shell of decomposed material, as shown in Fig. 3(*A*). The center portion of the lump was nearly the same color as that of the crude material. The fracture surface of the grains was glassy, but the grains were crystalline, unaltered olivine as shown by Fig. 10(*B*). Exposure of the fractured surface at room temperature to normal atmosphere turned the surface brown.

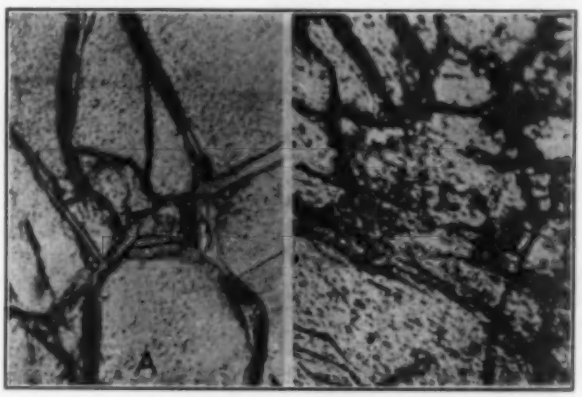

FIG. 10.—(*A*) Section of typical crude olivine; polarized light, ×80.
(*B*) Section from center of olivine lump (4 in. diameter) heated to 2710°F; fayalite has not decomposed; polarized light, ×80.

No oxygen or other gases had come in contact with this light-colored material. Oxidation had taken place along slip planes or other cracks that were not noticed before firing.

The largest grains that may be satisfactorily treated are approximately $^1/_4$ inch in diameter, but much smaller grains, passing 6-mesh and smaller, are more satisfactory. The decomposition in the smaller grains is more complete and takes place more rapidly with finer grinding.

The conversion agent should be as finely pulverized as possible to facilitate the conversion of the iron oxide and the formation of secondary forsterite. The best conditions could be reached by having a film of MgO surrounding each grain of olivine, such as is obtained by introducing the magnesia as a water-soluble salt.

The dissociation of the fayalite takes place as long as any oxygen other than that tied up in stable compounds is present at atmospheric pressure. Temperatures above that of normal room temperature are not necessary to promote oxidation; the rate of oxidation and the physical and chemical states of the oxide, however, are dependent on temperature and on the concentration of the free oxygen.

V. Summary and General Conclusions

The general practice in the manufacture of forsterite refractories at the present time necessitates temperatures of at least 2900°F or preferably 3000°F or above

in the firing operations. Magnesia or a magnesia-rich material may be incorporated with crushed olivine to eliminate the glassy phase.

If pulverized olivine is heated to 2700°F, certain chemical reactions will take place. The presence of magnesia as periclase has little or no effect at temperatures below 2700°F.

During the firing or calcining of a mixture of olivine grains and MgO, the fayalite and hydrosilicates of magnesia are decomposed. Iron oxide (ferrous) is completely removed from the fayalite by 1300°F and is deposited as Fe_2O_3 in the cleavage and parting planes of the remaining forsteritic material. A further rise in the temperature gradually converts the Fe_2O_3 to Fe_3O_4, which is precipitated at the grain boundaries. This Fe_3O_4, in the presence of the MgO, can be converted at 2900°F to $MgFe_2O_4$ by an atmosphere alternately oxidizing and reducing to Fe_3O_4. With temperatures of 3000°F and higher, the formation of $MgFe_2O_4$ will take place in an oxidizing atmosphere.

The silica from the fayalite remains within the forsteritic material producing a simple $MgO–SiO_2$ system, and it will have no liquid phase formed until 1557°C (2835°F), at which time approximately 10% of the mass of forsteritic material becomes liquid. This liquid will react with MgO to form forsterite.

Free oxygen in the atmosphere is essential to the decomposition of the fayalite, but it is not necessary for the decomposition of the hydrosilicates of magnesia. The grain size of the crushed olivine used in the manufacture of forsterite refractories should not be coarser than 3-mesh and preferably should be finer when the firing or calcining temperature is not over 2900° to 3000°F because the decomposition of the fayalite will not penetrate much more than $^1/_8$ inch.

Acknowledgment

The author wishes to thank A. F. Greaves-Walker for his guidance in this work and his aid in correcting the manuscript. Acknowledgment is also extended to the Tennessee Mineral Products Corporation, who furnished the olivine, and to the Canadian Refractories, Limited, who furnished the conversion agent. The aid in making the microscopic examinations so ably offered by J. L. Stuckey, head of the Department of Geological Engineering, Raleigh Unit, University of North Carolina, is appreciated.

Department of Ceramic Engineering
University of North Carolina, Raleigh Unit
Raleigh, North Carolina

SOME SHEET-IRON ENAMEL DEFECTS TRACEABLE TO THE BASE METAL OR METAL FORMING OPERATION*

By E. E. Howe

Abstract

Cross sections through defects that were encountered in different plants were studied for the possible causes of the trouble. The defects that were traceable to some faulty condition in the iron are reported. It was found that hairlines, depressed lines, and blisters in the enamel may originate from some unusual condition in the metal before enameling.

I. Introduction

Increased standards of quality of enamelware that necessitate more rigid inspection has brought about the recognition of defects unheard of several years ago. Because of the numerous sources of contamination as well as the complexity of the many variables entering into the enameling operations, the majority of the defects are traceable to some condition in the enamel shop. These factors and their relation to enamel defects have been the basis of numerous articles and considerable discussion, but at times the source of the trouble is so obscure and its detection so difficult that the base metal is blamed for want of a better explanation.

Instances have been observed, however, when the origin of the defect could be traced to some faulty condition in the underlying metal, and examples of this type of defect are described in this paper. A large number of samples has been collected, and the causes of the difficulties have been studied by means of the microscope.

Despite the number of instances in which steel has been blamed as the source of enameling difficulties, little effort seems to have been made to prove or disprove that the base metal was at fault, inasmuch as a review of the literature reveals but little information on the subject. Danielson and Souder[1] noted that an increased amount of copper in the base metal increased the tendency of the enamel to fishscale; Comstock[2] found that blistering in kitchenware white enamel was due to impurities in the iron; McGohan[3] reported that

* Presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 19, 1939 (Enamel Division). Received April 19, 1939.

[1] R. R. Danielson and W. H. Souder, "Causes and Control of Fishscaling of Enamels for Sheet Iron and Steel," *Jour. Amer. Ceram. Soc.*, **4** [8] 620–54 (1921).

[2] G. F. Comstock, "Some Causes of Blistering of Sheet-Steel Metal Enamels," *ibid.*, **6** [8] 873–85 (1923).

[3] G. W. McGohan, "Microscopic Technique in the Investigation of Enamel Coating and Some Observations," *ibid.*, **15** [7] 389–96 (1932).

the presence of segregated carbide areas in the iron gave rise to primary boiling of the ground-coat enamel; and Canfield and Taylor[4] discussed the causes of some enamel defects in relation to welding practices.

II. Scratched Metal

Fabricated parts occasionally reach the enamel plant with deep scratches on the face side. These marks can give rise to blister regions or lines in the cover-coat enamel or a combination of both, dependent upon the nature of the scratch itself. A typical example of this combined effect may be seen in plan view in Fig. 1(*A*), which is a photomacrograph of a piece cut from a fabricated part that contained scratches in the metal before enameling. The left side of the piece has been flexed several times, causing the enamel to break off and expose the base metal. The scratches in the metal and the resulting lines and blisters continuing into the enamel are clearly visible.

Figure 1(*B*) shows a photomicrograph of a section through the iron and enamel at a point near one of the blisters. The outline of the blister area is faintly visible in the center of the section (area free from bubbles), and directly under it may be seen a thin stringer of detached metal. This stringer is probably the result of an overlapping metal leaf produced when the part was scratched. These areas occur at irregular intervals and are a potential source of blistering owing to an entrapment of pickling solution or other foreign material.

There are times when a blister does not accompany the scratch, and in this case only a line becomes visible in the finished part. A cross section of iron and ground coat from a fabricated part that has been scratched prior to enameling is shown in Fig. 1(*C*). This section was made in such a way that the direction of the scratch was perpendicular to the face of the section so that the groove caused by the scratch is visible. The groove of the scratch appears as a depression to the left of the center, and a thin string of metal that has been forced out of the metal base may be seen to the right of the center of the section. The metal has been forced out of the groove leaving it open, with the result that contaminating material which might generate a gas was not entrapped.

[4] J. J. Canfield and A. E. Taylor, "Relation of Sheet-Welding Practices to Certain Porcelain Enamel Defects," *Proc. Porcelain Enamel Inst., Third Forum, Oct., 1938*, pp. 213–22; *Ceram. Abs.*, **18** [6] 150 (1939).

III. Welding Defects

(1) Hairlines

The appearance of a line of ground coat penetrating up through the cover enamel characterizes this defect. Hairlines frequently occur in the corners of edge-welded parts, such as refrigerator liners. A section through a hairline from the corner of a liner is given in Fig. 2, which shows clearly the penetration of the ground coat to the surface of the white finish coat. This condition results from a rupture of the cover enamel during its early firing stage, and the break is filled by the base coat enamel. Figure 2 may be compared with Fig. 3, which is a section from the same liner at a point at which hairlining did not occur. It seems probable in this case that the hairline was caused by metal movement during the enameling operation because of weakness at the weld. Note the thinning out of the metal in Fig. 2 at *A* as compared to the original thickness of metal at *B*. There may be a number of causes for this decrease in thickness at a weld, such as insufficient welding, too much grinding, or poor fit of the parts at the weld. Whatever the cause, if hairlines occur in corners of parts welded in this manner, the weld should be carefully inspected for some such condition as is evident in this case.

(2) Blistering

Blistering is the result of what might be termed an "open weld." Insufficient filling of the joined metal or the joining of two pieces of metal into a tapered form often results in a pocket that allows entrapment of pickling solutions with a later release of gases during firing. These gases may thus cause blistering in the overlying enamel layer. A defect of this type is shown in Fig. 4, a section through a roll-seam welded corner after enameling. The two pieces of metal taper toward each other before junction, leaving a crevice which may entrap foreign material. Such crevices do not have to be very large to cause trouble, and cracks of

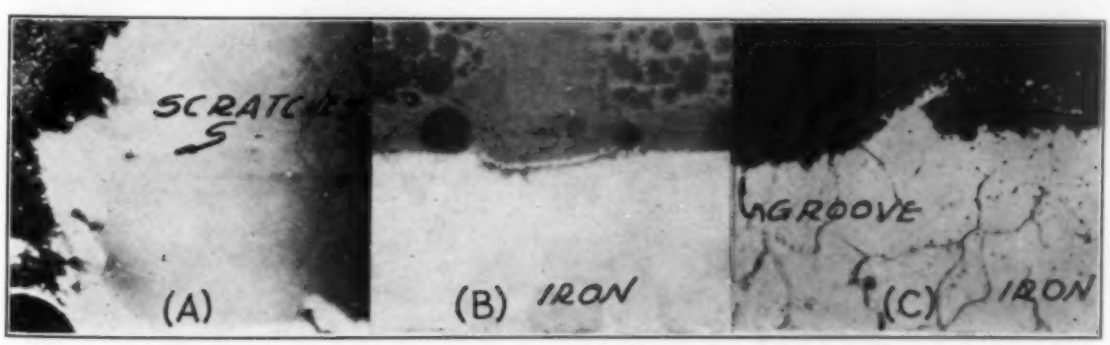

FIG. 1.—(*A*) Photomacrograph of defect caused by scratches in metal before enameling; ×2½. (*B*) Cross section through defect caused by scratched metal; ×100. (*C*) Depression caused by scratch in metal before enameling; ×500.

microscopic size in fact are generally more difficult to enamel than those that are larger and into which enamel can penetrate.

Blistering at a weld may also be caused by oxidized metal and improper selection of weld material as Canfield[4] has pointed out.

(3) Chipping

There are occasions when an incomplete weld does not show blistering or hairlining, but it may give rise to a different kind of trouble, *e.g.*, chipping on an outside corner. Every precaution was taken to keep the amount of enamel light at this spot but all to no avail. A cross section made through this area disclosed the fact that there was a break in the metal at a point directly under the chipped spot. The section is shown in Fig. 5(*A*) at a magnification of 10 diameters, and the break in the metal is barely visible at this magnification. The chipped area of enamel is indicated, and the uneven piece of metal to the left of the center is part of the weld material. The incompletely welded portion is shown at a higher magnification in Fig. 5(*B*). This crack is completely filled with oxide, a material which shows up as a dove-gray area in the photomicrograph. The presence of oxide indicates that the break was present before enameling.

IV. Primary Boiling

Blistering that occurs in the initial firing of the ground-coat enamel has been designated as "primary boiling." This phenomenon usually does not reappear upon subsequent firings of the enamel, and it is aggravated by black-edge application on the bisque. Several factors, such as improper pickling, incorrect application, and the enamels themselves have been blamed, but instances have been noted when this trouble occurred intermittently without any apparent change in the enameling operations. Examination under the microscope of sections prepared from panels displaying this defect has brought out the presence of segregated carbide areas in the steel as the contributing cause. A photomicrograph of a typical blister caused by carbides is shown in Fig. 5(*C*). The blister appears as a round black area, and the carbide segregation may be seen in the underlying iron as a network of small gray-appearing patches.

McGohan[3] reported that these iron-carbide areas could cause primary boiling in enamels, but he stated that they were common to mild steels rather than to enameling irons. In the instances noted, the iron employed by the plants having difficulty has been low-carbon stock intended to be used for enameling. Iron that displays this condition may usually be enameled successfully if the ground coat is applied light and fired down fairly hard before the application of any other coats of enamel.

Although enameling iron contains less than 0.05% carbon, this material can be harmful if it is segregated

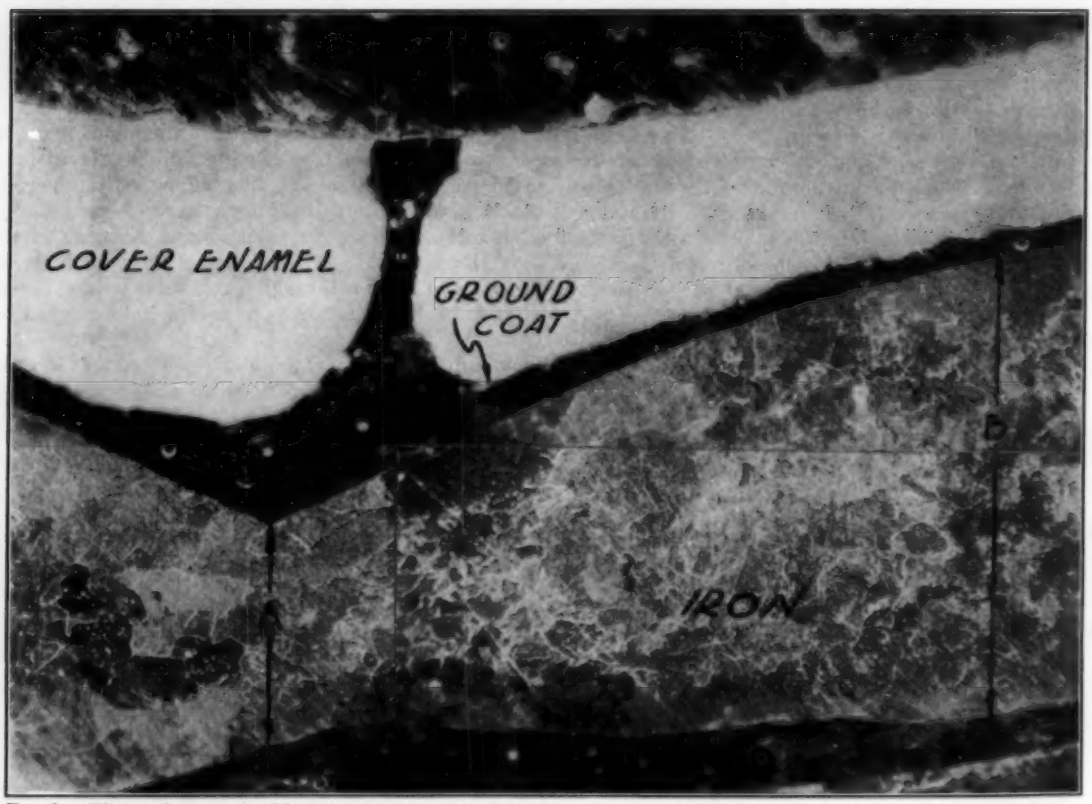

FIG. 2.—Photomicrograph of hairline in corner of refrigerator liner owing to weakened section at *A*; compare thickness of metal at *A* with that at *B*; ×60.

FIG. 3.—Section through welded corner of refrigerator liner at a point which did not hairline; note full thickness of metal; ×60.

into patches throughout the sheet. It is easy to detect these areas under the microscope although a chemical analysis would indicate that the iron was satisfactory. Inasmuch as enameling iron is essentially pure iron, the etched structure under the microscope discloses a network of lines that are the boundaries defining the individual grains of iron which go to make up the sheet. Iron is capable of retaining carbon in solution so that small quantities can not be detected under the microscope, but under certain heat treatments the carbon can be rejected in the form of a carbide of the chemical composition Fe_3C. This material that collects in spots is in an active form which oxidizes readily, forming a gas.

V. Inclusions in the Iron

(1) Oxide

Small inclusions in the surface of the enameling iron, such as rolled-in mill scale or slag, may give rise to blistering in the overlying layers of enamel. These inclusions show up as dove-gray patches in the iron (in the photomicrographs), and they do not need an etchant to bring out their presence. Figure 6, a section through enamel and iron, shows a blister in the enamel accompanied by an inclusion in the iron directly beneath it. The iron had been enameled with ground coat, and a black edge was applied over the bisque. The combination of these two enamels is conducive to blistering, owing to the increased thickness of the enamel layer.

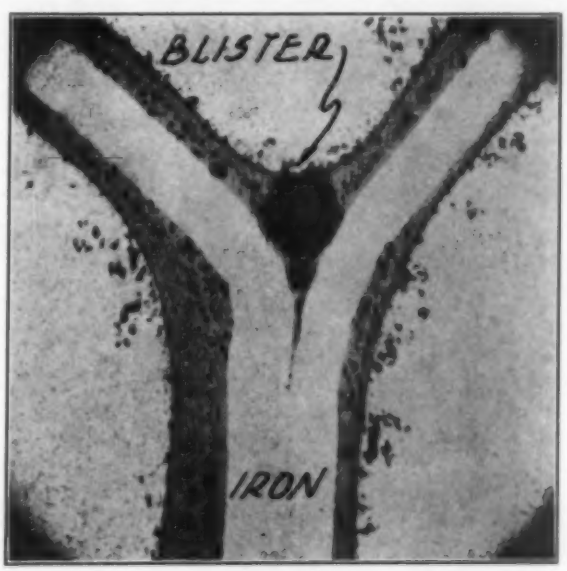

FIG. 4.—Blister in enamel (designated by arrow) caused by incomplete weld; ×10.

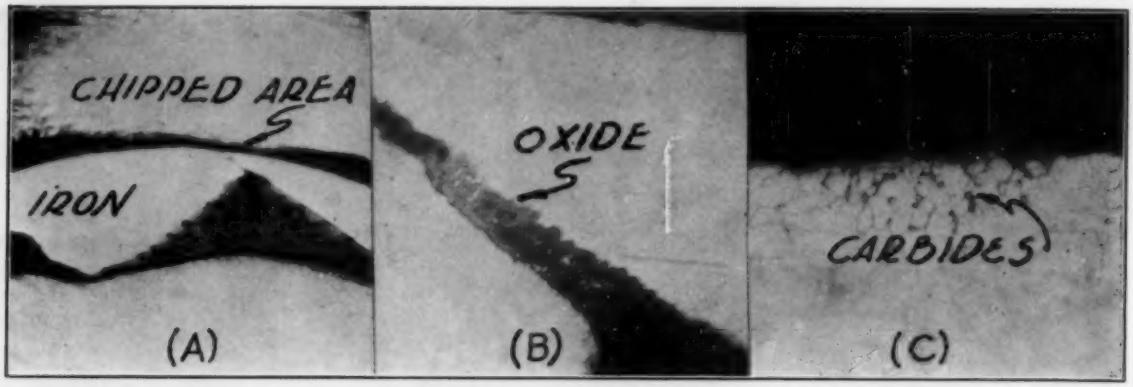

FIG. 5.—(*A*) Chipped corner of enameled part showing incomplete weld; ×10. (*B*) Incompletely welded portion of part shown in (*A*); note crack in metal filled with oxide; ×130. (*C*) Blister in enamel caused by carbide area near surface of iron; Nital etched; ×310.

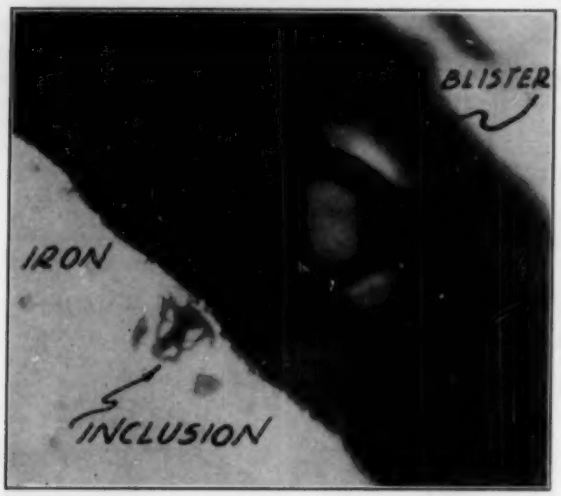

FIG. 6.—Blister in enamel resulting from inclusion in iron; ×310.

FIG. 8.—Imbedded steel grit particle in iron directly beneath large blister in enamel; ×100.

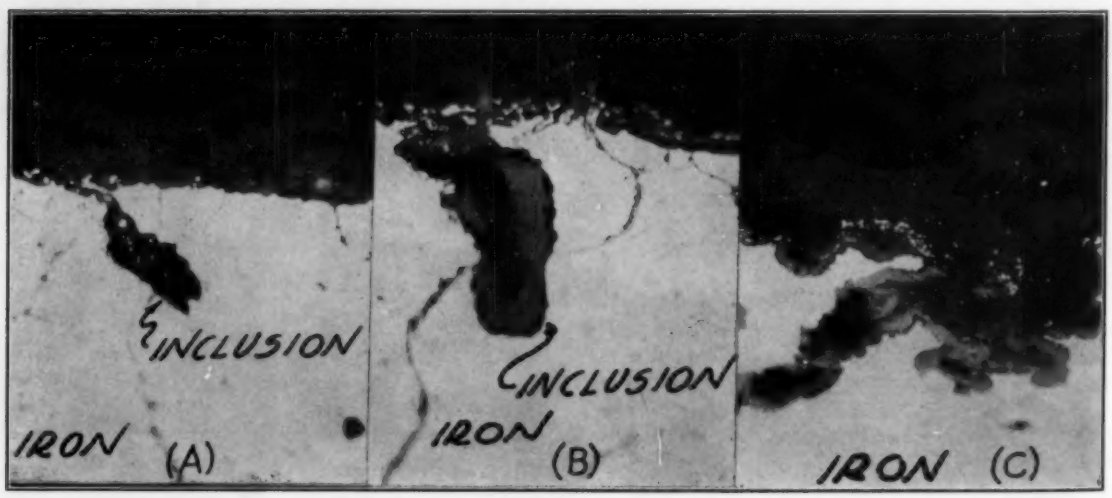

FIG. 7.—(*A*) "Bottle neck" inclusion in iron which caused blistering in cover-coat enamel; ×750. (*B*) Inclusion in surface of iron directly beneath large blister in enamel; ×750. (*C*) Section from a badly blistered enameled part; ×500.

FIG. 9.—Imbedded steel grit particle in iron before enameling; ×60.

A "bottle-neck" type of inclusion is shown in (*A*) and (*B*) of Fig. 7. These inclusions were encountered in sections made through blisters on panels that had been enameled with ground coat, regular cover coat, and an acid-resisting enamel finish coat. The plant experiencing this trouble found that the blistering was present on those pieces that had to be finished in acid-resisting enamel; there were no blisters in those parts that were finished in two coats of regular enamel. This condition is typical throughout the industry; the more viscous enamels, such as the acid-resisting types, are prone to aggravate any blistering condition that might be present. Trouble from inclusions of this kind may sometimes be alleviated by a change in the pickling practice, depending upon how near the surface of the sheet they lie. If the inclusions are deeply imbedded, light pickling will aid because a protective layer of iron remains to keep the enamel from coming in contact with the oxide in the pit. If the inclusion, on the other hand, is near the surface, a harder pickle will tend to etch the iron down to a point below the necked-in portion and thus leave an open pit that reacts with the enamel in the first or second firing and then causes no further trouble in the final fire. In cases where these inclusions are present, there is an increased tendency for the enamel to copperhead, owing to the release of a gas during the firing of the ground coat, which causes a rupture in the enamel layer and allows the hot furnace gases to produce localized oxidation.

Under certain enameling conditions, oxide inclusions in the iron may cause blistering in the ground coat without a black-edge enamel being applied. If such a situation is encountered, it is almost impossible to obtain a satisfactory enameling job. An example of this is shown in Fig. 7(*C*); this photomicrograph closely resembles those published by Comstock,[2] who also found that these inclusions may cause blistering.

(2) Steel Grit

One case of blistering was found to be due to the presence of a small steel grit particle imbedded in the surface of the iron. A section through a defect of this type is shown in Fig. 8, and the grit particle may be seen below the large blister which it has caused. It is almost impossible to cover a blister of this kind. By careful examination of the iron, several of the contaminated areas were found, one of which is shown in Fig. 9. The etched structure of the iron at the lower

FIG. 10.—(*A*) Section through copperhead caused by rolled-in steel sliver; ×170. (*B*) Portion of blister in enamel due to steel sliver in surface of iron; ×60. (*C*) Detail of steel sliver causing blister shown in (*B*); ×250.

corners of the particle indicates that the grit has become imbedded in the sheet after annealing has taken place because the grains still retain their elongated shape due to cold work.

It was found by experimentation that a force of 3000 pounds per square inch was required to imbed such a particle into the iron. Such pressure could be supplied by the rolls at the mill, and the probable source of the grit particle is from a temper mill roll which had been roughened by shot blasting to produce a roughened surface on the sheet.

(3) Steel Slivers

Slight imperfections in the surface of the metal caused by rolled-in slivers of steel will produce copperheads in ground coat and blisters in the cover-coat enamel. Figure 10(*A*) shows a section through a copperhead in the ground coat caused by a sliver of metal that had been imbedded in the surface of the sheet prior to enameling. The oxidized areas surrounding the particle may be seen in this figure. The depression in the base metal under the sliver indicates that it has been pressed into the sheet and is not a piece of free iron in the enamel itself.

Figure 10(*B*) shows a portion of a blister in the cover-coat enamel due to an imbedded metal sliver in the iron. The sliver is not clearly defined in this figure, but it may be seen at a higher magnification (Fig. 10(*C*)). The smaller grain structure of the metal fragment indicates that it is not an overlapping piece from the sheet.

VI. Summary

A microscopic examination of sections prepared of defects in sheet-iron enamels encountered in enamel plants throughout the country indicates that (1) depressed lines or a series of blisters in the cover-coat enamel may be caused by scratches in the surface of the iron; (2) hairlines in the corner of edge-welded parts after enameling may originate from insufficient metal thickness at the corner; (3) tapering welds and crevices caused by unwelded metal parts have caused blistering in enamel; (4) incomplete welding beneath an enameled outside radius is a potential source of chipping; (5) segregation of carbon in the form of carbides may sometimes cause primary boiling of the ground coat; and (6) blistering in the enamel may result from inclusions in the surface of the iron, such as slag, oxides, steel grit, and steel slivers.

Lusterlite Laboratories
Chicago Vitreous Enamel Product Company
Cicero, Illinois

A LABORATORY SLAGGING-TEST FURNACE WITH A ROTATING BURNER*

By R. K. Hursh

Abstract

A furnace is described in which uniform heat treatment and slag application is given to panels of test brick by means of a rotating gas burner through which the slag is fed in powdered form. Temperature gradients in the test panels and some test data are given.

I. Introduction

Considerable effort has been devoted to the development of a testing method to determine the relative attack by slags of various sorts on refractories. Owing to the variety of factors involved in the slag attack, testing procedures that simulate service conditions are much desired.

The equipment and testing procedure described here have been developed primarily for the study of the action of coal-ash slags under conditions similar to those in boiler furnaces. Slagging conditions in other than boiler furnaces may also be simulated in a testing furnace of this type.

To represent conditions of service related to slagging action on refractories, the temperature and atmospheric conditions in the test furnace should correspond closely with those of the industrial furnace. An equivalent temperature distribution or temperature gradient in the refractory should be maintained. It is essential that fresh slag be applied continuously or at regular and frequent intervals to the materials tested and that the composition of the slag correspond with that in the service represented. It is particularly important that all the refractories in the test be subjected to the same heat treatment and slag application in order that comparative results may be insured.

A major factor in the slagging action in many types of industrial furnaces is the washing action of slag flowing over the surface of the refractory. This effect should also be provided in the simulative service of the testing procedure.

II. Rotating Test Furnace

A rotating test furnace[1] was developed to study the

*Presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 19, 1939 (Refractories Division). Received April 19, 1939.

[1] (*a*) R. K. Hursh and C. E. Grigsby, "Laboratory Furnace for Testing Resistance of Fire Brick to Slag Erosion," *Univ. of Ill. Eng. Expt. Sta. Circ.*, No. 17 (Oct., 1928); *Ceram. Abs.*, **9** [12] 1059 (1930).

(*b*) R. K. Hursh, "Laboratory Slagging Test for Boiler-Furnace Refractories," *Trans. Amer. Soc. Mech. Engrs.*, **51** [22] 339–45 (1929); *Ceram. Abs.*, **9** [3] 195 (1930).

slagging of boiler-furnace refractories by coal ash. Powdered slag was fed through the fixed burner in such a way that it impinged and melted on the faces of the test brick as the furnace rotated. The slag flowed down the vertical faces of the brick and discharged through an opening in the bottom of the furnace. Operating difficulties were encountered owing to the effect of the high temperatures on the supporting rollers and on the driving mechanism of the furnace as well as the tendency of many slags to clog up the discharge opening. A further objection was the difficulty of measuring temperatures in the test brick to determine how the temperature gradient corresponded with that of service conditions.

This test furnace has been replaced by one in which the burner is rotated while the test brick remain in a fixed position. The method of slag application is essentially the same as that previously used.

The general construction of the furnace and a diagrammatic representation of the burner are shown in Fig. 1.

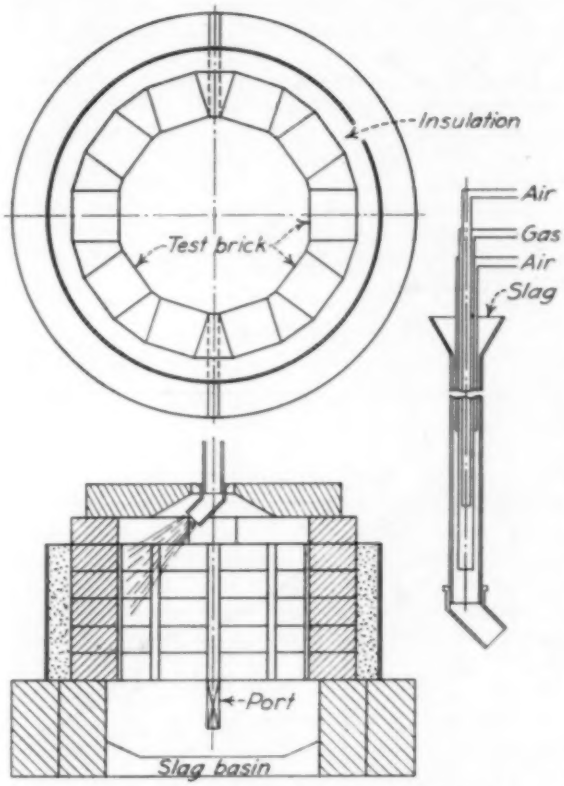

FIG. 1.—Slagging test furnace and burner.

(1) Description of Furnace

A base of 20 inches inside diameter was constructed of arch brick set on end. This was partly filled with coarse grog to permit the removal of the cake of slag which collects during the test. Panels of test brick of $4^1/_2$-inch thickness were built up on this base with spacers of arch brick or wedge-shaped blocks to form a circle 18 inches in inside diameter. The overhang of

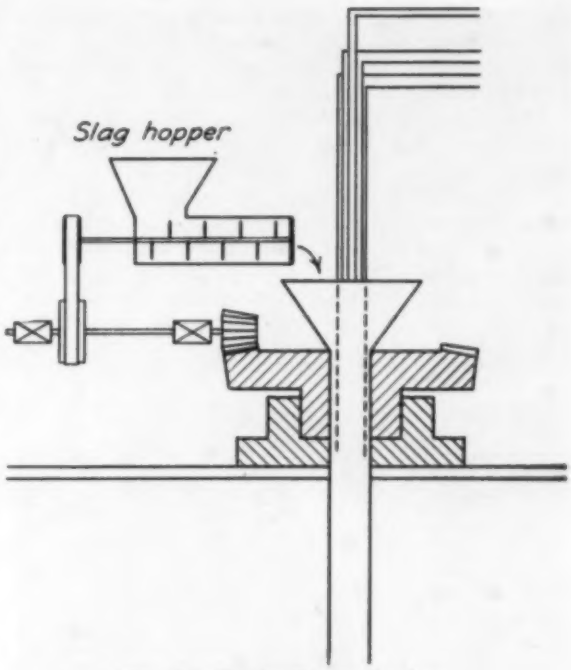

FIG. 2.—Slag-feeding mechanism.

the test panels permits the slag to drip off into the reservoir below. A jacket of hardware cloth and asbestos paper surrounded the circle of test brick and spacers with an intervening space of $1^1/_2$ to 2 inches for backup insulation. Granular expanded vermiculite has been found to be satisfactory for the purpose. Thermocouples may be inserted into holes drilled to various depths in test brick to determine the temperature gradients. The loose insulation and asbestos paper jacket facilitate the placing of the thermocouples.

The cover of the furnace was supported on pieces of brick to provide openings $2^1/_2$ inches high above the test brick for an outlet of combustion gases. It was also necessary to make two small openings or relief ports in the base of the furnace immediately below the test brick. These reduced the furnace pressure sufficiently to permit an adequate quantity of secondary air to be drawn in by the burner. A central opening in the cover, $4^1/_2$ inches in diameter, was provided for the burner.

The burner itself consists of three concentric copper pipes $^3/_8$, $^3/_4$, and 1 inch in diameter, respectively. Primary air is supplied through the center pipe, natural gas through the middle pipe, and air, when required, through the outer pipe. The $^3/_4$-inch gas pipe extends about 6 inches beyond the end of the inner air pipe, and the outer pipe is about 15 inches shorter. Compressed air is used, and the gas is supplied at 15-pound line pressure. Needle valves are used to control both the air and the gas. Union connections on the supply lines permit the easy removal of the burner at the end of a test.

The burner is suspended centrally in the vertical slag-feeding pipe, which constitutes the rotating part of

the burner assembly. This is a $1^1/_4$-inch wrought-iron pipe with a cone hopper at the top to receive powdered slag from the feeder. The pipe is fitted into a bevel gear resting in a bearing on the metal platform above the furnace, and it is rotated at 13 r.p.m. by a bevel pinion driven by a $^1/_4$-h.p. motor through a speed reduction train. The slag-feed pipe extends 6 to 8 inches below the end of the fixed burner and through the cover of the furnace. The lower end is fitted with a 45-degree street ell to direct the flame and slag against the test brick wall of the furnace. A coupling is provided in the slag-feed pipe above the furnace to permit dismantling and removal of the portion projecting into the furnace at the end of a test.

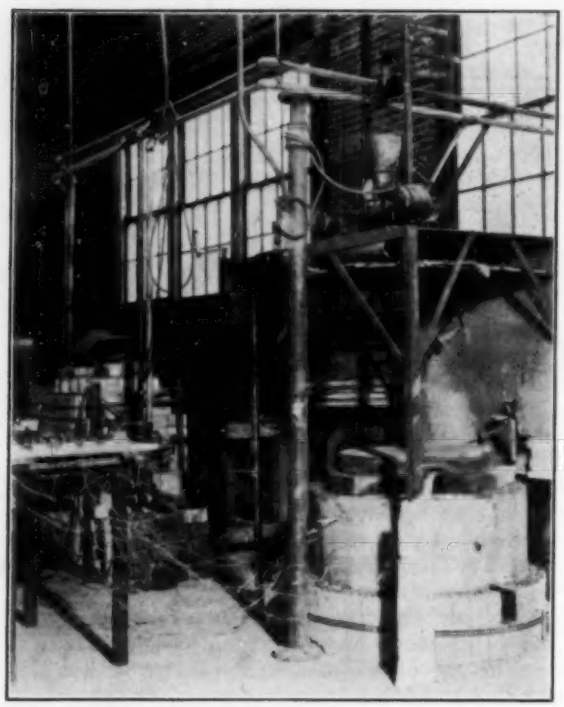

FIG. 3.—Slagging test furnace.

FIG. 4.—Interior of furnace after test.

(2) Slag-Feeding Mechanism

The slag-feeding mechanism is shown diagrammatically in Fig. 2. The powdered slag, ground to 20-mesh or finer, is delivered to the hopper of the rotating pipe by a small screw feeder with a double thread at the delivery end to insure more uniform discharge than is possible with a single-thread screw. The feeder is speeded to deliver about one pound of slag in three minutes. This rate of feed was selected more or less by chance and has seemed to be satisfactory, although a slower rate might be an improvement.

The entire furnace assembly is shown in Fig. 3 with the thermocouples in place to measure temperatures in test brick. The rotational and slag-feeding mechanism are placed on a metal platform well above the furnace with a transite shield below to give further protection from the heat.

The furnace is heated to the predetermined test temperature in 3 to 4 hours. Slag feeding is then started and continues for 8 hours or more. The burner is shut off and removed along with the extension of the feeder pipe which projects into the furnace. The furnace cover is lowered, and the top opening is covered for cooling.

Variations in the length of the slagging period have indicated that eight hours is probably the minimum to give comparative results with coal ash, although shorter periods have been found sufficient with some other types of slag. A somewhat longer period may be necessary with some slags, particularly for tests in the range of minimum temperature for slag action; long tests, however, are undesirable from the standpoint of labor and expense.

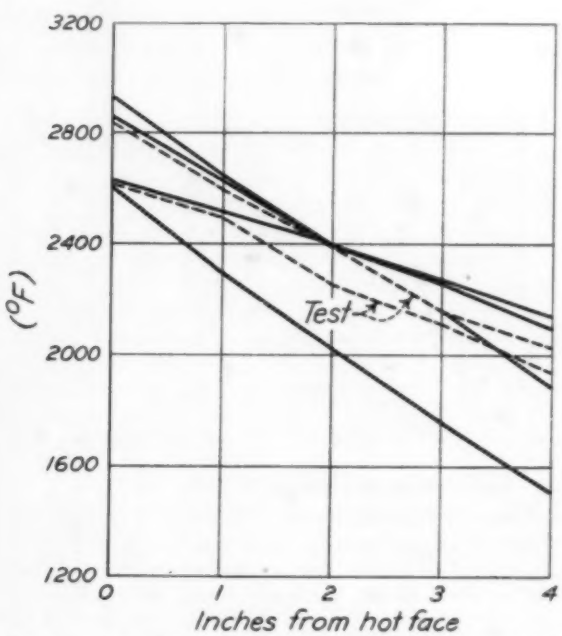

FIG. 5.—Comparison of temperature gradients in test brick with those in boiler furnace walls.

(3) Test Brick Arrangement

The arrangement of the test brick in the furnace wall has been varied. When brick are set on end, the vertical joints are sometimes eroded to such an extent that comparative results on different refractories are somewhat obscured. This arrangement is shown in Fig. 4. Wedge-shaped test samples also seem to have too small a face area for best results. Test panels made of half brick laid five high seem preferable. The horizontal joints give the same effect as those in the wall of a furnace lining and the rounding off of the edges of the panel along the vertical joint still leaves a considerable area of flat face for comparison.

Continuous and intermittent feeding of the slag have been tried. With the present rate of feeder operation, intermittent feeding has been the more satisfactory. Approximately one pound of powdered slag is charged every ten minutes. This is delivered through the burner in a 3-minute period, allowing the remainder of the interval for the slag to flow slowly down the faces of the test brick. With heavier feeding, much of the slag does not come into actual contact with the brick owing to the thicker coating. A slower and continuous rate of slag feed is to be tried.

The uniformity of slag application and heat treatment on the furnace wall are indicated in Table I by a comparison of erosion losses of panels of the same kind of brick placed at different positions in the wall.

TABLE I

UNIFORMITY OF SLAGGING TREATMENT ON DIFFERENT PANELS IN TEST FURNACE

(Test temp. 2600°F; length 8 hr.; slag used 54.5 lb.)

Refractory	Depth of erosion (in.) Panel No. (1)	(2)	(3)	(4)	(5)	(6)	Av.
A	0.08	0.09	0.10	0.10	0.09	0.09	0.09
M	0.21	0.22	0.21	0.20	0.20	0.20	0.20

The measurement of temperatures at different depths in the brick panels showed gradients closely like those in industrial boiler furnaces. The dotted lines in Fig. 5 show temperature gradients in two tests compared with gradients (solid lines) measured in the inner walls of several boiler furnaces. Variations in gradient may be controlled by the amount of backup insulation around the furnace.

III. Conclusion

The criterion of a simulative service test is the comparison of the results with those on the same refractory materials in service conditions. In order to get such a comparison in the present test, observations are being made on test panels in boiler furnaces in the power plant at the University of Illinois, and laboratory tests are being conducted on the same refractories with the same coal-ash slag and at temperatures corresponding with those of the boiler furnace. Adjoining panels of fifty or more brick are built in the furnace wall in the zone of greatest erosion and are inspected and photographed at every shut-down. For convenience in replacement, these are built beneath an arch in the side wall (see Figs. 6 and 7). The actual service data can only be obtained slowly, but eventually the comparison with test-furnace results should provide a true measure of its effectiveness.

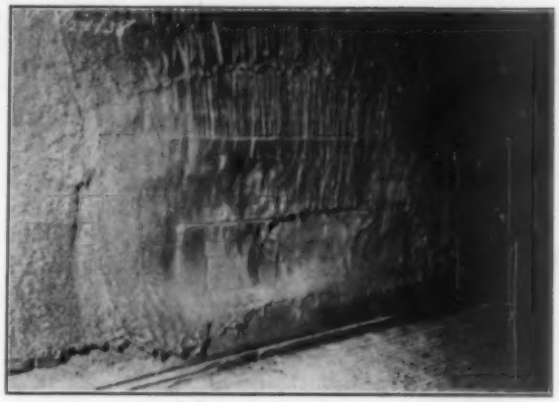

FIG. 6.—Test panels in boiler furnace inner wall.

FIG. 7.—Test panels in boiler furnace outer wall.

DEPARTMENT OF CERAMIC ENGINEERING
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

THE AMERICAN CERAMIC SOCIETY TRUSTEES AND OFFICERS FOR 1939–1940

President: A. I. Andrews, University of Illinois, Urbana, Ill.
Vice-President: J. L. Carruthers, Ohio State University, Columbus, Ohio
Treasurer: C. Forrest Tefft, The Claycraft Co., Box 866, Columbus, Ohio
Secretary-Editor: R. C. Purdy, 2525 North High St., Columbus, Ohio
Past-President: V. V. Kelsey, Dominion Minerals, Inc., 719—15th St., N. W., Washington, D. C.
Past-President: R. B. Sosman, United States Steel Corp., Research Lab., Kearny, N. J.

TRUSTEES FROM INDUSTRIAL DIVISIONS*

Art: L. E. Barringer, General Electric Co., Schenectady, N. Y. (1940)
Enamel: H. G. Wolfram, Porcelain Enamel & Mfg. Co., Baltimore, Md. (1940)
Glass: D. E. Sharp, Hartford-Empire Co., Hartford, Conn. (1941)
Materials and Equipment: H. B. DuBois, Consolidated Feldspar Corp., Trenton, N. J. (1942)
Refractories: C. E. Bales, Ironton Fire Brick Co., Ironton, Ohio (1940)
Structural Clay Products: A. F. Greaves-Walker, Univ. of North Carolina, Raleigh, N. C. (1942)
Terra Cotta: F. B. Ortman, Gladding, McBean, & Co., Los Angeles, Calif. (1942)
White Wares: E. H. Fritz, Westinghouse Electric & Mfg. Co., Derry, Pa. (1941)
Institute of Ceramic Engineers: R. E. Birch, Harbison-Walker Refractories Co., Pittsburgh, Pa. (1941)
Ceramic Educational Council: A. S. Watts, Dept. of Ceramic Engineering, Ohio State Univ., Columbus, Ohio (1941)

* Date of expiration of term of office in parentheses.

DIVISION OFFICERS

Art
Chairman: J. P. Thorley, Parkway, East Liverpool, Ohio
Secretary: C. C. Engle, United Clay Mines Corp., Trenton, N. J.

Enamel
Chairman: W. H. Pfeiffer, Frigidaire Div., General Motors, Eng. Lab., Dayton, Ohio
Secretary: D. G. Bennett, Mellon Institute, Pittsburgh, Pa.

Glass
Chairman: N. W. Taylor, Pennsylvania State College, State College, Pa.
Secretary: S. R. Scholes, N. Y. State College of Ceramics, Alfred, N. Y.

Materials and Equipment
Chairman: William Malkin, B. F. Drakenfeld & Co., Inc., East Liverpool, Ohio
Secretary: W. H. Emerson, Homer Laughlin China Co., Newell, W. Va.

Refractories
Chairman: S. F. Walton, Exolon Co., Blasdell, N. Y.
Secretary: Gilbert Soler, Steel & Tube Div., Timken Roller Bearing Co., Canton, Ohio

Structural Clay Products
Chairman: C. R. Austin, Battelle Memorial Institute, Columbus, Ohio
Secretary: J. H. Isenhour, Isenhour Brick Co., Salisbury, N. C.

Terra Cotta
Chairman: H. E. Davis, Federal Seaboard Terra Cotta Co., South Amboy, N. J.
Secretary: D. F. Albery, Charleston Vitreous Clay Products Co., Charleston, W. Va.

White Wares
Chairman: Karl Schwartzwalder, AC Spark Plug Co., Flint, Mich.
Secretary: Harry Thiemecke, Homer Laughlin China Co., Newell, West Va.

OFFICERS OF THE FELLOWS

Dean: S. R. Scholes, New York State College of Ceramics, Alfred, N. Y.
Associate Dean: Edward Schramm, Onondaga Pottery Co., Syracuse, N. Y.
Secretary-Treasurer: T. N. McVay, University of Alabama, University, Ala.

LOCAL SECTIONS

Baltimore-Washington
Chairman: J. D. Tetrick, Baltimore Enamel & Novelty Co., Baltimore, Md.
Secretary: Kenneth M. Smith, Severn Clay Co., 2618 St. Paul St., Baltimore, Md.

Central Ohio
Chairman: W. C. Rueckel, Battelle Memorial Institute, Columbus, Ohio
Secretary: G. H. Duncombe, Jr., Battelle Memorial Institute, Columbus, Ohio

Chicago
President: A. L. Vodicka, Aetna Porcelain Enameling Co., Chicago, Ill.
Secretary: Rexford Newcomb, Jr., Industrial Publications, Inc., Chicago, Ill.

Michigan-Northwestern Ohio
Chairman: L. G. Tait, Champion Spark Plug Co., Detroit, Mich.
Secretary: J. A. Foster, Ford Motor Co., Dearborn, Mich.

Northern California
Chairman: A. S. Adcock, American Radiator & Standard Sanitary Co., Richmond, Calif.
Secretary: G. A. Page, Stockton Fire Brick Co., Pittsburg, Calif.

Pacific-Northwest
President: F. G. Burrows, Chehalis Brick & Tile Co., Chehalis, Wash.
Secretary: Hewitt Wilson, Electrotechnical Lab., Bureau of Mines, Norris, Tenn.

Pittsburgh
Chairman: Ernest Hommel, O. Hommel Co., Pittsburgh, Pa.
Secretary: C. L. Thompson, Harbison-Walker Refractories Co., Pittsburgh, Pa.

Southern California
Chairman: H. R. Goodrich, Gladding, McBean, & Co., Los Angeles, Calif.
Secretary: J. G. Stewart, Braun Corp., Los Angeles, Calif.

St. Louis
Chairman: H. M. Tostlebe, General Refractories Co., Clayton, Mo.
Secretary: P. G. Herold, Missouri School of Mines, Rolla, Mo.

COMMITTEE ON PUBLICATIONS

Chairman: J. D. Sullivan, Battelle Memorial Institute, Columbus, Ohio
A. N. Finn, National Bureau of Standards, Washington, D. C.
E. E. Marbaker, Mellon Institute, Pittsburgh, Pa.
W. W. Winship, Thermal Syndicate, New York, N. Y.
R. C. Purdy, 2525 North High St., Columbus, Ohio
Editorial and Advertising Offices:
The American Ceramic Society, 2525 North High Street, Columbus, Ohio

CERAMIC ABSTRACTS

Compiled by the

AMERICAN CERAMIC SOCIETY

Ross C. Purdy, Editor

ABSTRACTERS

J. B. Austin	M. V. Condoide	J. J. Hazel	Yosio Kora	Katherine Reed	E. W. Stenzel
A. A. Ayars	P. S. Dear	F. G. Heck	Walther Kurz	H. K. Richardson	A. G. Stern
L. R. Barrett	Maurice Delangre	R. A. Heindl	B. B. Lane	B. C. Ruprecht	Joseph Stewart
K. W. W. Bartlett	R. W. Devillers	P. G. Herold	V. S. de Marchi	A. B. Searle	B. H. Strom
A. C. Bevan	Joseph Ford	G. M. Hutt	L. F. May	Stanford Setchell	L. E. Thiess
D. A. Biddle	W. D. Foster	J. F. Hyde	E. H. McClelland	G. R. Shelton	Hans Thurnauer
W. H. Bruckner	V. D. Fréchette	Herbert Insley	J. M. Noy	N. M. Shukri	P. V. Tooley
P. Budnikoff	J. L. Gallup	C. B. Jenni	J. G. Phillips	H. E. Simpson	E. J. Vachuska
J. C. Chaston	J. D. Gat	B. Z. Kamich	Alexis Pincus	A. P. Som	F. E. Vaerewyck
L. M. Church	R. A. Gregory	B. E. Kinkulkin	M. E. Poor	E. Stefanowski	F. J. Zvanut
W. M. Cohn	Max Hartenheim	S. Kondo	C. H. Rapp		

Journal Reference: The journal name appears in italics, followed by the volume (bold-faced), issue number (in brackets), page numbers, and year (in parentheses).

October, 1939
18—10

Abrasives

Cutting fluids and the machine tool. A. H. Lloyd and H. H. Beeny. *Jour. Inst. Petroleum Technologists*, **24**, 650–54 (1938). **Discussion.** *Ibid.*, pp. 672–91. W.D.F.

Developments in thread-grinding practice. Paul V. Miller. *Mech. Eng.*, **60** [10] 741–43 (1938). F.G.H.

Functions of cutting fluids. H. W. Swift. *Jour. Inst. Petroleum Technologists*, **24**, 662–71 (1938).—Cutting fluids are aqueous solutions, oil emulsions, straight oils, and "doped" oils with sulfur, graphite, etc. To reduce friction losses, a slightly sulfurized oil is best; for heat dissipation, an aqueous solution or emulsion is used. The only satisfactory test for a cutting fluid is direct use. With a sulfurized oil, reduction of torque varied from 7% to 30% on various steels. A jet of fluid directed against the top of the chip improved tool performance 34%, but when the jet was directed against the tip of the tool from below, the improvement was 70%. **Discussion.** *Ibid.*, pp. 672–91. W.D.F.

Grinding and lapping of hard metal tools with diamond. Heinz Frank. *Werkstatt & Betrieb*, **72** [13–14] 180–84 (1939).—Diamond grinding wheels are in general use for grinding, polishing, and lapping hard carbide tools after they are preground with silicon carbide. Diamond must be used from the beginning in certain cases, viz., for large thin surfaces, for very accurate shapes which cannot stand increase in temperature, and for end milling cutters and other complicated shapes. Diamond wheels are dressed with silicon carbide hand files. The finest grains in use, 3/1000 mm., 1.5/1000 mm., and 0.5/1000 mm., are used for the lapping and polishing of carbide tools as well as for other purposes (precision instruments, balances, etc.). Bakelite is used as a bond for wheels used in hand grinding. Metal is chiefly used as bond (brass, bronze, steel, and metal carbides). Diamond is used not only imbedded but also on the surface. Diamond powder on cast-iron wheels is the most economical for the finest grain. It is also used on wood, felt, and Bakelite. The best speeds are 15 to 30 m./sec. for grinding and 5 to 30 m./sec. for lapping and polishing. J.M.N.

Manufacture of cutting oils. John F. Miller. *Jour. Inst. Petroleum Technologists*, **24**, 645–49 (1938). **Discussion.** *Ibid.*, pp. 672–91. W.D.F.

Modern fine grinding and lapping materials. Karl Frank. *Werkstatt & Betrieb*, **72** [11–12] 169 (1939).—F. describes the different applications of fine grinding and lapping and classifies the materials, according to their use, in grades A to G, starting with the coarsest and ending with the finest grain. He does not give composition data but enumerates the objects for which the different grades are used. For fine grinding, grades A to D are preferred; for polishing and lapping, grades E to G are most suitable. Grade G is to be used with benzine and kerosene only, and it gives exact surfaces of 1/10,000 mm. For higher speeds, F. prefers benzine to kerosene. J.M.N.

Refinement of ground surfaces. Herbert S. Indge. *Mech. Eng.*, **60** [11] 807–12 (1938).—I. describes the methods, processes, and equipment used to produce superfine finishes on metal parts required for accurate machine construction under the following headings: (1) lapping, (2) honing, (3) superfine grinding, and (4) crankshaft and camshaft finishing. The abrasives required for these finishing methods are discussed in detail. The refinement of ground surfaces must be planned by experienced engineers. Surface finishes are built up, finer abrasives being used for each subsequent operation. Lapping and honing operations permit the production of refined surfaces at high production rates as well as at extremely moderate cost. Illustrated. F.G.H.

Selection of cutting fluids. H. J. Mason. *Jour. Inst. Petroleum Technologists*, **24**, 655–61 (1938).—The main types of cutting fluids are (1) soluble oil and (2) straight oil. Soluble oil is generally preferable because of its cheapness and cleanliness. It has been used successfully in almost all types of machining operations. **Discussion.** *Ibid.*, pp. 672–91. W.D.F.

Smoothness tester. Yaekichi Sekiguchi and Ichiro Hasegawa. *Mech. Eng.*, **60** [10] 751–55 (1938).—A method of measuring surface roughness by means of a smoothness tester which utilizes the piezoelectrical phe-

nomenon is described. It is especially sensitive for measuring the smoothness of a ground surface because of its ability to discern differences which cannot be detected with the naked eye. Types of abrasives and methods of grinding are considered in detail with respect to their effect upon the smoothness of the ground product. Illustrated. F.G.H.

BOOKS

Grinding Practice. F. H. COLVIN AND F. A. STANLEY. McGraw-Hill Book Co., New York, 1937. 310 pp. Price $3.00. Reviewed in *Mech. Eng.*, **60** [2] 174 (1938).—Abrasive wheels and modern grinding equipment are thoroughly described. F.G.H.

Tool Room Grinding. F. B. JACOBS. Penton Publishing Co., Cleveland, 1937. 221 pp. Price $3.50. Reviewed in *Mech. Eng.*, **60** [1] 93 (1938). F.G.H.

PATENTS

Abrading crankshafts. FRANK POSTMA. U. S. 2,167,311, July 25, 1939 (Sept. 17, 1937).

Abrading device. A. V. BREED (Curtis Machine Corp.). U. S. 2,166,676, July 18, 1939 (July 30, 1937).

Abrading element. FRANK POSTMA. U. S. 2,167,312, July 25, 1939 (Nov. 5, 1937).

Abrading, polishing, and buffing device. WILLIAM H. BAUCH. Can. 382,822, July 25, 1939 (Nov. 12, 1937). G.M.H.

Abrasive or hard-wearing compositions. W. J. TENNANT (Carborundum Co.). Brit. 508,486, July 12, 1939 (Dec. 30, 1937).

Abrasive supporting pad. R. C. BENNER, C. E. WOODDELL, AND C. S. NELSON (Carborundum Co.). U. S. 2,167,037, July 25, 1939 (Dec. 30, 1935).

Abrasive wheel. EDWARD VAN DER PYL (Norton Co.). U. S. 21,165, July 25, 1939 (April 28, 1938); reissue of original 2,072,051 (*Ceram. Abs.*, **16** [5] 142 (1937)).

Buffing wheel. J. F. WHITE. U. S. 2,167,059, July 25, 1939 (Aug. 12, 1938).

Cam-grinding apparatus. H. A. SILVEN (Norton Co.). U. S. 2,167,614, July 25, 1939 (Dec. 27, 1937).

Control apparatus for grinding machines. D. R. HALL (Gardner Machine Co.). U. S. 2,168,596, Aug. 8, 1939 (Sept. 12, 1935).

Cylinder honing and wiping device. G. C. BECK. U. S. 2,166,281, July 18, 1939 (Dec. 6, 1937).

Device for grinding or honing long bores. MASCHINENFABRIK AUGSBURG NÜRNBERG AKT.-GES. Brit. 508,291, July 12, 1939 (Jan. 5, 1938).

Grinder and control valve therefor. F. P. FORSS (Independent Pneumatic Tool Co.). U. S. 2,166,757, July 18, 1939 (March 3, 1938).

Grinding or abrading machines. HEALD MACHINE CO. Brit. 509,304, July 26, 1939 (Nov. 3, 1937); addition to 483,279, April 27, 1938.

Grinding device. AVERY W. WALKER (Carborundum Co.). Can. 382,907, July 25, 1939 (May 17, 1937); see *Ceram. Abs.*, **17** [5] 170 (1938). G.M.H.

Grinding and lapping machines. NORTON CO. Brit. 506,976, June 21, 1939 (July 31, 1937).

Grinding machine. V. W. GIDEON (Boyar-Schultz Corp.). U. S. 2,167,647, Aug. 1, 1939 (April 29, 1938).

Grinding machine steady rest. H. A. SILVEN (Norton Co.). U. S. 2,167,615, July 25, 1939 (May 13, 1938).

Grinding wheel and method for cooling. D. Z. MURPHY. U. S. 2,167,282, July 25, 1939 (April 16, 1938).

Honing machines. A. F. BURGESS (Barnes Drill Co.). Brit. 508,286, July 12, 1939 (Dec. 8, 1938).

Machines for grinding pens or pen nibs, etc. H. MITCHELL AND J. BATEMAN. Brit. 508,410, July 12, 1939 (March 12, 1938).

Method and machine for honing cylindrical surfaces. A. M. JOHNSON AND W. M. FAIRBAIRN (Barnes Drill Co.). U. S. 2,167,758, Aug. 1, 1939 (March 18, 1938).

Method and means for polishing the surface of precision ground articles. A. G. WALLS. Brit. 507,136, June 21, 1939 (Sept. 7, 1937).

Method and means for use in surface grinding dents on dismounted flat bars used in carding engines. J. DRONSFIELD. Brit. 508,411, July 12, 1939 (March 19, 1938).

Portable grinder. W. C. DRAHEIM. U. S. 2,166,861, July 18, 1939 (Oct. 17, 1938).

Razor-honing apparatus. FREDERICK SCHMID (Charles Romano). U. S. 2,166,773, July 18, 1939 (Oct. 25, 1937).

Resinoid-bonded abrasive article. BAALIS SANFORD (Norton Co.). U. S. 2,168,281, Aug. 1, 1939 (Jan. 12, 1938).—An abrasive article comprises abrasive grains bonded by a resinoid bond containing prevulcanized, nonbonding, substantially nonresilient hard rubber particles interspersed therethrough.

Segmental abrasive wheel. H. W. H. BETH (Norton Co.). U. S. 2,168,283, Aug. 1, 1939 (Nov. 3, 1937).

Slideway for wheel carriages of gear-grinding machines. ARTHUR STEPHAN (J. E. Reinecker A.-G.). U. S. 2,168,275, Aug. 1, 1939 (Sept. 21, 1937).

Truing of grinding wheels. REISHAUER-WERKZEUGE A.-G. AND A. RICKENMANN. Brit. 508,681, July 19, 1939 (Nov. 29, 1937).

Twist-drill grinding attachments. J. A. YANTISS. Brit. 509,214, July 26, 1939 (Oct. 18, 1938).

Valve grinder. F. T. SWEIGART. U. S. 2,168,458, Aug. 8, 1939 (March 7, 1936; renewed Jan. 7, 1939).

Ventilated buff. L. M. HAGUE (Hanson-Van Winkle-Munning Co.). U. S. 2,168,871, Aug. 8, 1939 (April 29, 1939).

Art and Archeology

Barbers' bottles recommended. EDITH COLLEY. *Amer. Home*, **20** [2] 12, 55 (1938).—The collection of the many varieties of barbers' bottles is described and illustrated. F.G.H.

Ceramics from the Eumorfopoulos collection. A. D. BRANKSON. *Brit. Museum Quart.*, **13** [2] 46 (1939).—B. describes two vases believed to be from the Yung-ho dynasty; the second vase may have been made in the 14th century. Illustrated. A.B.S.

Chinese influence on English tableware. ANON. *Ceramics in Art & Ind.*, No. 2, pp. 14–21 (1939).—Chinese influence on the designing of tableware has always been strong in England; Doulton & Co. has produced many designs in which it is clearly shown and a ware which, from both technical and artistic viewpoints, is the equal of that made by the master of the Sung dynasty, Chang the Elder. Illustrated. A.B.S.

Collecting lion glass. L. B. MAYNE. *Amer. Home*, **18** [5] 21, 127–28 (1937).—M. describes the characteristics of a type of Sandwich glass known as lion glass. All lion pieces are clear, with either frosted collar bases, decorated with reclining lions and small palm trees, or frosted standard bases. Every dish cover is topped by a lion head, a crouching lion, or a rampant lion, each frosted. The pattern has historical significance, for the cable edge of all the lids of the covered dishes, as well as the bases, commemorates the laying of the first Atlantic cable. Illustrated. F.G.H.

Collecting luster. MYRL TAYLOR FIELDS. *Amer. Home*, **19** [4] 30–31, 86–88 (1938).—F. gives a brief history of lusterware and describes the fundamental principles involved in the production of various types. Illustrated in color. F.G.H.

Early American castors. HARRIET S. SHIELDS. *Amer. Home*, **18** [5] 64, 67 (1937).—Illustrated. F.G.H.

English drinking jug comes back. DOMINA DRIEMEN. *Amer. Home*, **19** [3] 36, 61–62 (1938).—Pottery and china caricatures in the form of drinking jugs are described and illustrated. F.G.H.

Figures in china. ANON. *Ceramics in Art & Ind.*, No. 2, p. 22 (1939).—For some years prior to 1928, china figures were seldom used for interior decoration. They

now fill an important place in modern homes where they introduce color and character. Illustrated in color. A.B.S.

Four porcelain figurines. *Coronet*, **6** [4] 55–58 (1939).—Full-page color illustrations of examples from the Chelsea factory. The first, "Quinn in the character of Falstaff," is from the Museum of Fine Arts, Boston. "The Picnic" is an example of the transition period, 1759–1770, and carries the anchor mark. Descriptive of the everyday life of the time is "Boy and Girl Shelling Peas," and "The Music Lesson," adapted from a François Boucher painting, shows unusually fine workmanship. M.E.P.

Garden loveliness in old glassware. BESSIE M. LINDSEY. *Amer. Home*, **20** [2] 23–24, 53–54 (1938).—Flower patterns in old glassware are described and illustrated in detail. F.G.H.

Glass collecting. EVELYNE MANO LAMBRECHT. *Amer. Home*, **19** [2] 22–23, 57–58 (1938).—Short cuts in the collection of old glass are discussed. Illustrated. F.G.H.

Guide to Italian Majolica: Chapter II, Historical position and origin of Italian faience. BERNARD RACKHAM. Translated in *Céram., Verrerie, Email.*, **7** [3] 95–98 (1939).—The post classic age in Italy yielded only simple pottery for domestic use. A revolution in technique and achievement occurred when the Italian potters came in contact with the Near Eastern influence of Persia, Mesopotamia, Syria, and Egypt and learned the secret of the preparation of opaque, white, tin enamel which is the distinctive characteristic of majolica and supplies the necessary smooth white background for decorative painting. This knowledge was the primordial condition for the development of the majolica art in Italy, and in this nation of painters, the painting on majolica, which began as a decorative adjunct to a utilitarian object, eventually came to be the sole motive for the creation of that object. This is justified by the fact that a faience plate is as suitable for painting as wood or canvas, and ceramic pigments are not only more durable than oil or tempera but possess individual chromatic qualities of great value. Majolica as an art reflected the spirit of humanism of the times; mythological and Biblical scenes were interpreted according to the fantasy of the artists. See *Ceram. Abs.*, **15** [1] 5 (1936). M.V.C.

Historical blue Staffordshire ware. MALCOLM WATKINS. *Amer. Home*, **19** [5] 31–32, 81–85 (1938).—W. gives a brief history of blue Staffordshire ware. Illustrated in color. F.G.H.

Medieval pottery vessels. R. L. S. BRUCE MITFORD. *Brit. Museum Quart.*, **13** [2] 35 (1939).—M. describes a piece of stoneware, of great rarity and considerable archeological importance, found at Oxford but identical with and typical of others made at Pingsdorf in the Rhineland in the Carolingian period (9th to 11th century) and also in East Anglia. A tall jug on a sharply waisted foot, typical of early Plantagenet pottery (not earlier than A.D. 1275), is also described. Illustrated. A.B.S.

Mound of Tarsus. HETTY GOLDMAN. *Asia*, **39**, 413–18 (1939).—This mound, Gozlu Kule, lies on the southwest edge of the modern city. It was chosen because it was in virgin territory and might be the meeting point of neighboring civilizations. It had been inhabited until recent years. At the top is an Islamic layer, followed by a Roman layer, and then a layer showing a typical Hellenistic town at the time of Alexander. The pottery from 1000 to 600 B.C. was Cypriote in style but was made locally, as shown by the discovery of a large pottery with ware in every stage of manufacture. Next below was the upper of two layers, both contemporary with the new Hittite empire (1450 to 1200 B.C.). The culture was Hittite, but Mycenaean sherds made just before the citadel fell were also found. The next layer contains some of the finest buildings found. The following layer, corresponding to the older Hittite empire, shows this culture sometimes mixed with that of North Syria. The level just below has pots stamped with cylinder seals and two-handled cups which are a variant of Troy II–III. In the next level, the earliest examined, a heavy wall and gate were found. The pottery consisted of cups, small jugs, etc., made from a red ware with a highly burnished slip. W.D.F.

Old Irish glass. Its character, design, and decoration. G. B. HUGHES. *Chambers' Jour.*, pp. 197–98 (March, 1939); *Jour. Soc. Glass Tech.*, **23** [96] 116A (1939).—Glasshouses existed at Dublin in 1675, at Waterford in 1768, and at Cork in 1782. Three characteristics which distinguished old Irish glass from other kinds were tone, texture, and hardness. It was impossible to discern any difference between very early Irish glass and English glass of the same period, as it was made by English workmen, of English materials, and often after English patterns. The excessive presence of lead oxide in its composition was responsible for the peculiar bluish, blackish, or greenish gray tint common to most Irish glass made before 1830. Cork glass was rarer than Waterford. Glass from the Belfast glasshouse had a yellowish tint. Most pieces of old Irish glass bore no distinguishing mark.

Old patterns in new glass. ANON. *Amer. Home*, **20** [2] 25 (1938).—Illustrated. F.G.H.

Painting on pottery. ANON. *Ceramics in Art & Ind.*, No. 2, pp. 23, 28 (1939).—The use of paintings on tile for wall decoration is discussed. Ten illustrations. A.B.S.

Pottery making in China. MARVIN O. LEWIS. *Ceram. Ind.*, **28** [4] 347–50 (1937).—A typical Chinese community devoted almost entirely to the manufacture of pottery is described. The clays are shipped in on the river, mixed by hand, and shaped by hand or on a potter's wheel. River mud forms the base of the glazes, various additions being made to obtain colors. Wood is used in firing the kilns, which lie on the hillsides at the edge of the town. Most of the ware is of poor quality. E.J.V.

Pressed glass. JULIET B. PICKETT. *Amer. Home*, **19** [6] 17, 104–108 (1938).—Numerous early pressed-glassware patterns are described and illustrated. F.G.H.

Romance of etched glass. ANON. *Amer. Home*, **20** [6] 63–64, 88–89 (1938).—The manufacture of etched glassware is described and illustrated. F.G.H.

Stoneware of today. ANON. *Ceramics in Art & Ind.*, No. 2, pp. 25, 31 (1939).—The beautiful work of Vera Huggins and Joan Cooper in stoneware is described. Illustrated. A.B.S.

Structural materials for kitchens. W. M. MEHLHORN. *Amer. Home*, **20** [1] 31–32, 54 (1938).—M. discusses the use of clay tile and glass in the modern kitchen. Illustrated. F.G.H.

Temple in the Hadhramaut. G. CATON-THOMPSON. *Asia*, **39**, 294–99 (1939).—The temple is located in South Arabia near the Gulf of Aden on an eminence with an artificial depression to the southwest. It has an oblong raised platform with two flights of stairs. The floor is of flags set in cement. It had been enlarged twice. Nearby tombs are caves in sandstone. The pottery found there is asymmetric, monochrome, handmade, coarse, and badly fired. Much of it is inscribed in pre-Arabic lettering, similar to that found at Ezion-Geber (*Ceram. Abs.*, **18** [6] 146 (1939)). The people were traders and probably lived from the 4th century B.C. until Roman times. W.D.F.

Terra-cotta dog. I. E. S. EDWARDS. *Brit. Museum Quart.*, **13** [2] 43 (1939).—E. describes a recumbent dog which is an outstanding example of Egyptian art in the Roman period. Illustrated. A.B.S.

Three German glasses. W. KING. *Brit. Museum Quart.*, **13** [2] 38 (1939).—K. briefly describes a covered goblet (about A.D. 1600), a plate of amber glass made for the Fugger family at Augsburg (no date), and a tumbler painted in red with four figures in the style of Callot, probably South German (A.D. 1720). Illustrated. A.B.S.

SEPARATE PUBLICATIONS

Chemically prepared oxides and hydrated oxides of iron. British Standard Specification No. 851—1939. BRITISH STANDARDS INST., London, May, 1939. Price 2s.—

Marigold, maroon, and yellow iron oxides and hydroxides of iron of two types, "pure" and "reduced," are included. The percentages of ferric oxide, of coarse particles, of matter volatile *in vacuo* over sulfuric acid, of matter soluble in water, and of carbonates and oil absorption, color, staining power, and the mode of sampling are specified. Though primarily intended for materials used as pigments, the specification is also useful for some ceramic materials. A.B.S.

Ziggurat and Its Surroundings. LEONARD WOOLLEY. British Museum, London. Price £3 12s 6d.—W. describes the best preserved of the Babylonian temple towers, that of the Chaldees at Ur. The building and its history are fully described. It is of interest to ceramists because it was built largely of brick. 88 illustrations. A.B.S.

PATENTS

Apparatus for stencil decorating. J. C. SMITH (Solar Laboratories). U. S. 2,166,269, July 18, 1939 (June 28, 1937).

Designs for:

Bottle. J. L. BICKS (Carr-Lowrey Glass Co.). U. S. 115,778, July 18, 1939 (May 8, 1939). E. M. COBB (California Growers Wineries). U. S. 115,782, July 18, 1939 (April 20, 1939). J. L. DUNNOCK (Swindell Bros., Inc.). U. S. 115,784, July 18, 1939 (May 8, 1939). F. R. HOCH (T. J. Holmes Co., Inc.). U. S. 115,790 to 115,792, July 18, 1939 (Nov. 15, 1938).

Bottle. KIST CANADA, LTD. Can. 12,469, July 8, 1939. G.M.H.

Combined pitcher and cover. R. E. KRUCK (Westinghouse Electric & Mfg. Co.). U. S. 115,833, July 25, 1939 (Jan. 10, 1939).

Dish. R. A. MAY (Duncan & Miller Glass Co.). U. S. 115,935, Aug. 1, 1939 (May 5, 1939).

Glass cream pitcher. F. S. BARBIERS (Anchor-Hocking Glass Corp.). U. S. 115,828, July 25, 1939 (May 13, 1939).

Glass goblet. T. C. HEISEY (A. H. Heisey & Co.). U. S. 115,819, July 18, 1939 (May 24, 1939).

Glass jelly dish. T. C. HEISEY (A. H. Heisey & Co.). U. S. 116,030, Aug. 8, 1939 (May 8, 1939).

Glass relish dish. T. C. HEISEY (A. H. Heisey & Co.). U. S. 115,818, July 18, 1939 (May 15, 1939).

Goblet. A. J. CUNNINGHAM. U. S. 115,731 to 115,758, July 18, 1939 (April 27, 1939). GEORGE SAKIER (Fostoria Glass Co.). U. S. 115,799, July 18, 1939 (April 26, 1939).

Jar. O. C. NOBLE (Tygart Valley Glass Co.). U. S. 116,048, Aug. 8, 1939 (June 9, 1939).

Jug. B. D. FUERST (Owens-Illinois Glass Co.). U. S. 115,848, July 25, 1939 (May 20, 1939).

Light-diffusing glass. W. F. M. HAWE (Consolidated Lamp & Glass Co.). U. S. 115,816, July 18, 1939 (March 21, 1939). U. S. 115,817, July 18, 1939 (April 22, 1939).

Perfume bottle. COLGATE-PALMOLIVE-PEET CO., LTD. Can. 12,437, June 17, 1939. G.M.H.

Plate. GEORGE SAKIER (Fostoria Glass Co.). U. S. 115,800, July 18, 1939 (April 26, 1939). VICTOR SKELLERN (Josiah Wedgwood & Sons, Inc.). U. S. 115,767, July 18, 1939 (March 11, 1939). A. M. WALKER (Bailey-Walker China Co.). U. S. 115,840, July 25, 1939 (Jan. 6, 1939).

Cements

Ancient mortars from Rumania. A. STEOPOE. *Ciment si Beton*, **4**, 1–9 (1936); *Chem. Abs.*, **33**, 5148 (1939).—Four mortars from old Roman structures contained additions of hydraulic constituents, e.g., brick dust and volcanic rock, with 12% of soluble SiO_2. The formation of CO_3 ion was less and the amount of H_2O of hydration was higher as the proportion of hydraulic constituents increased.

Characteristics of cement particles of different sizes. R. ARIANO. *Strade*, **20**, 351–58 (1938); *Chem. Abs.*, **33**, 5147 (1939).—Examination of the size-weight distribution of (1) a Portland, (2) a blast-furnace, (3) a high-Al_2O_3, and (4) a pozzuolanic cement showed that the quantity of the finest fraction (0 to 10 μ) was greatest for the high-Al_2O_3 cement, followed by the Portland cement, the pozzuolanic cement, and the blast-furnace cement, while the quantity less than 85 μ was least for the Portland cement, followed by the blast-furnace cement, the high-Al_2O_3 cement, and the pozzuolanic cement. The distributions agreed with those calculated from Roller's formula. Data are given on the density of the fractions. The high-Al_2O_3 and Portland cements contained the greatest quantity of dark-colored particles, and the pozzuolanic cement contained the greatest quantity of the light-colored particles.

Pozzuolana and pozzuolana cements. F. E. V. *Verre & Silicates Ind.*, **10** [15] 171–73; [16] 183–85 (1939).—V. describes the characteristics of natural and artificial pozzuolanas and discusses the determination of pozzuolanic activity; lime bond in pozzuolana mortars; tests, uses, and properties of mortars, cements, and concrete; and chemical resistance to aggressive media. M.V.C.

Recent tendencies in Portland cement composition: I, Critical analysis of the data and of the influence of specifications. II, Phase relationship of cement compounds. J. E. WORSDALE. *Jour. S. African Chem. Inst.*, **22**, 3–15 (1939); *Chem. Abs.*, **33**, 5147 (1939).—W. gives a short historical sketch of the chemistry of Portland cement, starting with Le Châtelier's work and following with Rankin and Wright's of the Geophysical Laboratory of Carnegie Institute, and Hauser, Brownmiller, and Bogue's of the National Bureau of Standards, emphasizing Bogue's "Compound Composition." A chronological list of the opinions of various workers is given, including those of Lea and Parker of the Building Research Station of England, which upset Bogue's calculations. Dealing with the work of Lea and Parker, using a 3-component phase diagram for white cement and 4-component phase diagrams for commercial cements, W. suggests that some modifications to Lea and Parker's thesis are necessary, because of the presence of MgO and alkalis, and that further research work be done to explain the properties of cement during the hydration of its various phases. He stresses the large amount of research done on Portland cement in the U. S., especially at the National Bureau of Standards.

Sodium silicate cements. F. D. SNELL. *Chem. & Ind.*, **57** [3] 62–63 (1938).—Quick-setting cements, requiring no surface treatment of the joints to be completely insoluble, are insoluble in strong and weak acids and in water. One type is composed of 100 parts aggregate, 25 parts dry sodium silicate having the ratio $Na_2O:SiO_2$ of 1:2 and a moisture content of the order of 20%, and 23 parts sodium fluosilicate. A more recent composition of 100 parts aggregate and 9.4 parts sodium fluosilicate mixed with 70 parts of liquid sodium silicate in the ratio of 1:3.25, containing 38% of actual sodium silicate, gives a cement having a working time of 15 to 20 min. before the initial set. G.R.S.

Stockholm symposium on the chemistry of cements. ANON. *Chem. & Ind.*, **57** [33] 771–72 (1938); *Zement*, **27** [43] 671–75 (1938).—Papers read at the first international discussion on chemical problems relating to cements since that held by the Faraday Society about 20 years ago are listed. G.R.S. + F.E.V.

PATENT

Manufacture of cement. SOC. ANON. DES CIMENTS DE THIEU AND L. BLONDIAU. Brit. 508,736, July 19, 1939 (April 17, 1937); addition to 437,855.

Enamel

Blasting machine cleans without injuring parts. American Foundry Equipment Co. *Steel*, **102** [4] 68 (1938).—The Wheelabrator Tablast blasting machine throws abrasive by centrifugal force while the work is carried on rotary tables. The machine cleans small fragile articles without scratching or injuring them but exposes minute hairlines, cracks, and defects. See "Multirotary—," *Ceram. Abs.*, **17** [1] 2 (1938); "High—," *ibid.*, **15** [10] 294 (1936). H.E.S.

Blistering of porcelain enamel on cast iron. E. E. Howe and M. E. Manson. *Foundry*, **65** [11] 35, 95 (1937).—Blistering is caused by the breakdown of combined carbon during the enameling process and the formation of carbon monoxide and carbon dioxide gas which is entrapped in the enamel in the form of large bubbles. An iron containing all of its carbon in the form of graphite will not blister. An iron in which the combined carbon is so stable that no breakdown occurs at enameling temperatures and one in which the combined carbon is so unstable that a nearly complete breakdown occurs before the enamel coat fuses probably will not blister. When the stability of the carbides is of such a degree that a gradual dissociation takes place throughout the enamel firing period, the iron will blister. Irons exhibiting the latter characteristic are poor annealing irons. Most blistering castings have a thin skin or microchill in which the carbides are comparatively more stable than those in the body of the casting. Illustrated. See "Cast-iron—," *Ceram. Abs.*, **13** [6] 143 (1934). F.G.H.

De-enameling process. Anon. *Sprechsaal*, **72** [22] 286–87 (1939).—Chemical and patented mechanical processes of de-enameling are briefly described. M.V.C.

Electric kiln in the enamel industry. K. Samson. *Sprechsaal*, **72** [8] 96–97 (1939).—S. describes a new revolving-hearth furnace in which the ground enameling and the powder enameling can be coupled in the same firing process. The grate is circular and travels through the heating zone at a definite speed. The enameled ware is introduced through the charging door, placed on the moving grate, and heated at a definite rate to the necessary temperature. The ware reaches the second door and is removed from the grate, powdered, and returned to the furnace; it proceeds to the next firing zone where the powder is fired and then to the charging door to be removed. The speed is so regulated that removal and charging of the grate is easily accomplished. The output of the furnace is 4500 kg. of charge per 24 hr. with a current requirement of 85 kw. The furnace is heated from the sides and above and is divided into three regulated zones, two for ground enameling and one for powder enameling. The diameter of the revolving hearth is 1700 mm., the diameter of the hearth is 800 mm., and the height is 400 mm. The outer diameter of the furnace is 3500 mm., and the height is 1500 mm. The rational operation of the furnace yields greater output and minimizes heat loss. A new highly efficient chamber kiln with a permanent grate is also described. Its measurements are as follows: outside width 2250 mm., length 4000 mm., height 1900 mm.; interior width 1250 mm., depth 3000 mm., height over the grate 800 mm.; grate width 1000 mm., length 2600 mm. M.V.C.

Enameling reagent for copper plate. Tatuo Irie and Hideo Tunoda. *Repts. Imp. Ind. Research Inst., Osaka, Japan*, **18** [4] 52 pp. (1937).—Experiments on an enameling reagent for copper plate gave the following conclusions: For the lead-bearing ground coat, the total amount of quartz and feldspar must be less than 44%. Red lead should range from 32 to 40%; with increasing red lead, the ground coat adheres well but becomes greenish. Fluorite is better than limestone as a source of CaO. The addition of a small amount of magnesium oxide gives good results. BaO and ZnO are also suitable reagents. Ground coats which do not contain lead adhere well; they do not corrode the copper plate and therefore do not become greenish. Ground coats containing 40 to 48% of siliceous substance give good results, and a small addition of zinc oxide is very effective. A white cover-coat enamel containing arsenious acid was also studied. Increasing silica increases melting points and causes the ware to craze badly; 32 to 38% silica is suitable. When silica is replaced by alumina to a small extent, good results are obtained. Increasing boric acid increases opacity but also increases shrinkage, bubbles, and cracks. When red lead exceeds 26 to 34%, the enamel becomes yellowish. Potassium carbonate is better than soda ash as a source of alkali. The addition of lime, magnesia, barium oxide, or zinc oxide is not desirable for cover-coat enamels. Y.K.

Evolution of kilns in the enamel industry. R. Aldinger. *Glashütte*, **69** [22] 385–87 (1939).—A. reviews the history of kilns for more than a century. The first furnaces were made like ceramic muffle kilns with a cast-iron muffle heated with charcoal. The surface of the muffle rarely exceeded 1 x 0.60 m. This type was used until 1870, when larger muffles of grog were constructed in Belgium. Dimensions were extended to 2.50 x 0.80 m. surface and 0.80 m. height, and these are maintained today. The combustion chamber was placed in back of the furnace and adapted for a gas generator. Improvement in the quality of refractories prolonged the muffle life to a year or more. After the World War, larger and longer muffles were made. M.V.C.

Granite enamel. Anon. *Emailwaren-Ind.*, **16** [23–24] 151–53 (1939).—Granite enamel is the correct designation for enamels containing granite, but it is applied to a series of gray enamels which are either speckled or sprayed; it is not clear whether the term refers to the appearance or the stability. Methods of producing the granite appearance are described briefly. Batches for granite enamel by Bull and others are given. M.V.C.

Inhibitors for acid-pickling processes. J. S. Walton. *Sheet Metal Ind.*, **12** [134] 693–94 (1938).—Inhibitors in pickling baths (1) save acid, (2) prevent overpickling and eliminate surface pitting and iron waste, (3) are less liable to form blisters, and (4) reduce the evolution of obnoxious fumes. Only a small quantity of inhibitor is required, and the pickling operation is not prolonged. A.P.S.

Molding sands and facings with reference to vitreous enameling. H. McNair. *Foundry Trade Jour.*, **58** [1129] 297–98, 300 (1938).—The effect of carbonaceous facings on enamel adherence was studied by determining the force (in lb./sq. in.) required to pull two enameled test pieces ($^1/_4$ in. thick and 1 in. in cross-sectional area, i.e., 1.128 in. in diameter) apart. When shot-blasting was used, the mold facings gave the following order of adhesive value: (1) plumbago, (2) patent blacking, (3) lampblacking, (4) wood blacking, and (5) coal dust. Annealing does not improve the adhesion of the enamel to the metal. Shot-blasting shows a marked improvement in adherence. See *Ceram. Abs.*, **17** [11] 348 (1938). H.E.S.

Opacification of enamels by zirconium oxides. Deneuville. *Céram., Verrerie, Email.*, **7** [4] 118 (1939).—The opacity of enamels is caused by the reflection, refraction, and diffraction of light by particles present in the vitrified material. Diffusion of the light results and gives the opaque appearance. The refractive index of the particles must be different from that of the glass; structure is also important, for crystals and small particles have a higher diffusing power. Dispersion increases the intensity of the phenomenon. If the dimensions of the dispersed particles are of the order of the wave lengths of the light, there will be diffraction. Diffraction increases to a maximum when the size of the particles diminishes; then it is reduced. Maximum opacity is attained when the large particles give refraction and intense reflection and the small particles produce optimum diffraction. There is evidently a decomposition of the white rays of light followed by erratic recomposition. Opacification may be produced by (1) additions of insoluble pulverized opacifiers to the mill, (2) additions to the frit of compounds which devitrify and crystallize into small crystals when cold, (3) the for-

mation of another glass in the enamel which does not mix with it, and (4) fine dispersion of air bubbles. These different processes of opacification are used together. The value of a zirconium oxide is not in its purity or high ZrO_2 content but in its physical constitution. Zirconium oxide produced by the electric process in the U. S. is excellent; it forms no gas and can be used for enameling directly on the metal. M.V.C.

Opacifying enamels with gas. ANON. *Verre & Silicates Ind.*, **10** [13] 145–46; [14] 158–59; [16] 181–82 (1939).—Opacification with gas is growing in importance because it is much cheaper and the necessary ingredients are found in all countries. In opacifying with gas, the frit of white enamel, which has already been partly opacified and whose chemical composition has been specially studied, receives additions to the mill of organic materials which decompose during firing and form minute bubbles of gas; these do not go through the surface of the enamel in considerable quantities. Opacity is obtained because the index of refraction of the gas bubbles is lower than that of the enamel. Only small amounts of organic materials (0.3 to 1.0%) are required for opacification, and optimum amounts for obtaining maximum opacity with ordinary firing and an acceptable surface in case of overfiring must be ascertained by tests in every case. Gas opacifiers contain, besides organic matter, small amounts of absorbing or diluting "vehicles," principally clay or the sodium and ammonium salts of mineral acids, which increase brilliance, favor the formation of gas, maintain the consistency of the enamel frit, etc. Gas opacification may be combined with opacification with tin oxide or other solid opacifiers to increase opacity. Enamels suitable for gas opacification have a higher fluorine content and are called colloidal. They are introduced in the form of sodium fluosilicate. M.V.C.

Porcelain finish imitates snowflakes. J. M. SEASHOLTZ & SONS, INC. *Steel*, **103** [6] 56 (1938).—The material forming the crystalline pattern is applied by either spraying or brushing after the cover-coat enamel has been fired on. Under the correct atmospheric conditions the material dries into crystals of various shapes and design which become hard. Oxide pastes can be applied over this to form any variety of colors and are subsequently fired at usual temperatures to form the finish coat. The crystalline effect produced is an integral part of the enamel and is permanent. H.E.S.

Production efficiency at Ingram-Richardson Frankfort plant. ANON. *Ceram. Ind.*, **28** [3] 208–11 (1937).—A detailed description of the plant and operations at the Ingram-Richardson Mfg. Co., Frankfort, Ind., is given. E.J.V.

Sand control for better castings. H. W. DIETERT. *Metals & Alloys*, **10** [3] 90–95 (1939).—D. discusses the effect of the type of sand on the casting quality of various metals and the simple methods available for testing, controlling, and standardizing the grades and quality of foundry sand used. The main characteristics of any sand mixture are moisture, grain size, and clay content. Special test equipment is illustrated. J.J.H.

Silicates in place of silicic acid. VIELHABER. *Emailwaren-Ind.*, **16** [21–22] 138–39 (1939).—Silica raw materials are profitable for enamels in which the silicic acid is in the amorphous rather than in the crystal state. The high silica content is retained and affords chemical resistance or economy in flux material with less effect on the expansion due to heat; the softening point and firing temperature are not raised. The mineral geyserite of Taunus is suggested for use in this case; its composition is SiO_2 99.43, CaO 0.18, Fe_2O_3 0.04, Al_2O_3 0.20, and loss on firing 0.13. Infusorial earth (diatomaceous earth) contains too much iron oxide except for ground enamels. M.V.C.

Wetting agents in metal cleaning. D. J. BENOLIEL. *Ceram. Ind.*, **28** [6] 520–22 (1937).—Wetting-out agents were studied when freshly made up and after being boiled in alkali for four days, and the relative cleaning speeds of a standard anhydrous sodium resinate and of alkali when treated with wetting-out agents were measured. Only the sulfonated cresol compounds retained their original wetting-out ability after four days of boiling. A "strip" method for controlling alkaline cleansing baths consists in using test strips coated with a standard grease or oil and observing the time required to remove all the oil from the strip to give a surface without a water break. See "Chemistry—," *Ceram. Abs.*, **16** [9] 267 (1937). E.J.V.

BOOK

Enameling of Cast Iron (Emaillierung des Gusseisens). E. SCHÜTZ. Wilhelm Knapp, Halle (Saale), 1937. 150 pp. Price 6.45 Rm. Reviewed in *Mech. Eng.*, **60** [3] 262 (1938).—Raw materials, the preparation and composition of enamels, and ovens and methods are described. F.G.H.

PATENT

Continuous strip pickling method and apparatus. R. A. CRITTEN. U. S. 2,166,583, July 18, 1939 (Jan. 15, 1938).

Glass

Annealing glassware. GEORGE ROESSLER. *Ceram. Ind.*, **28** [3] 221–26 (1937).—Strains are already in the glass when it becomes rigid and can therefore best be eliminated by allotting a greater proportion of the total annealing time to the critical period just before the glass ceases to be ductile. The temperature at which rigidity sets in, rather than the initial temperature of the ware, should be used as a guide for formulating the annealing curve. After the temperature drops below this point, the thermal drop may be very rapid. R. suggests new temperature conditions to aid in the engineering of a better lehr. E.J.V.

Arsenic in glassmelting. E. S. *Sprechsaal*, **71** [36] 440 (1938).—The uses of arsenic in glassmelting for purifying and decoloring are briefly discussed. See *Ceram. Abs.*, **18** [6] 151 (1939). M.V.C.

Beginning of the plate-glass industry in Belgium. Foundation of the crystal glass factories of Saint-Louis Munzthal, Vonêche, Baccarat, le Val Saint-Lambert, and Namur. JOSEPH DE DORLODOT. *Verre & Silicates Ind.*, **9** [24] 280–82; [26] 302–306 (1938); **10** [3] 27–32 (1939).—The origin of the glass industry at Baccarat is discussed. As at Vonêche, a glass factory preceded the crystal factory. The Bishop of Metz wished to exploit the products of the vast forest of the castle of Baccarat and obtained authorization to establish a glass factory in 1765 at the location of the present crystal factory. A glassmaker, Antoine Renault, was put in charge, and the factory flourished until the revolution. In 1816, d'Artigues obtained possession of the factory and began the manufacture of crystal. See *Ceram. Abs.*, **16** [8] 239 (1937). M.V.C.

Cobalt blue glass ground and polished. AMERICAN OPTICAL CO. *Steel*, **103** [17] 44 (1938).—A standardized ground and polished cobalt blue glass for use in viewing open-hearth furnace operations has been developed. Glass of this nature formerly was either drawn or blown and had surface irregularities injurious to vision. Available in eight shades, this glass is used by furnace operators as a visual means of determining temperatures and conditions of melt where heat-measuring instruments are impractical. H.E.S.

Curious lens fracture. G. J. JONES. *Optician*, **96**, 350 (1938); *Jour. Soc. Glass Tech.*, **23** [96] 108A (1939).—The shell frame of a pair of spectacles was broken, and the 3.5 D biconvex lens was stuck into the frame with seccotine. Three days later the lens fractured spontaneously with a circular fracture, leaving a 2 to 3 mm. ring of the peripheral portion of the lens stuck in the frame.

Dielectric losses in glass at high frequencies due to relaxation. D. I. SKANAVI. *Zhur. Tekh. Fiz.*, **9** [7] 612–23 (1939).—An attempt was made to calculate the dielectric penetration and $tg\delta$ which are conditioned by

the presence of alkali ions in small concentrations. Losses in solid amorphous bodies can occur on account of the admixed ions, and they can be calculated on the basis of a polarization model (for simple bodies). The presence of a maximum $tg\delta$, which is characteristic for relaxation losses, is levelled down by other processes such as conductivity (technical frequency), so-called structural losses, and conductivity (high frequency). For B-alkaline glass, the concentration of the added oxide should not be over 15% of the alkali oxide. At higher concentrations the structure of the glass undergoes a change, the ions interact, and the mechanism of losses becomes complicated with other processes. The time of relaxation at 600°K should be over 10^{-7} sec. because the temperature maximum of $tg\delta$ at a frequency of 10^7 is possible only at much higher temperatures. At room temperature the time of relaxation should be about 10^{-2} to 10^{-3} sec. The time of jumping of the ion on the diameter of the sphere shows it to be equal to 10^{-12} to 10^{-13} sec., and only at very high temperatures (above tg) does it become equal to the time of relaxation. B.Z.K.

Effect of neutralization and crystallization in reducing high voltage losses in glasses. G. I. Skanavi and K. I. Martyushok. *Zhur. Tekh. Fiz.*, 9 [11] 1024–31 (1939).—This research was conducted to find a method for decreasing the dielectric losses in glasses. The relation between the angle of dielectric losses, the concentration of alkali oxides, and the temperature was determined for B and silicate glasses. The results are given in curves and indicate that there is a neutralization effect applicable to the glasses. The temperature of crystallization and the angle of dielectric losses of B-Na-Li glasses pass a minimum when the summary concentration of NaLi is 64 or 128 atoms per 100 mols. of B_2O_3. The physical nature of the neutralization effect is not clear. The neutralization effect, however, may be used to decrease the angle of dielectric loss and the conductivity of glasses; thus, partial substitution of K for Na in technical glasses may produce a considerable decrease in the angle of losses. It is also possible to use Pb and other metals for neutralization. The following glass had the minimum angle of losses: SiO_2 29.7, PbO 64, and Na_2O 63 parts. B.Z.K.

Effect of surface tension on seedy glass. K. C. Lyon. *Ceram. Ind.*, **28** [2] 138 (1937).—The atmospheric pressure on a glass melt is the main factor in preventing the expansion of seeds as they rise toward the surface. The effect of the surface tension is minor except in the case of very small bubbles. In a tank furnace the rate of rise of bubbles is sometimes accelerated by the action of currents in the glass. The higher temperatures encountered near the glass surface tend to cause an expansion of the gas of the bubbles and a lowering of the surface tension, both of which allow the growth of the seed. See "Maximum—," *Ceram. Abs.*, **17** [8] 275 (1938). E.J.V.

End-fired glass tank has operating advantages. Thomas B. Hart. *Ceram. Ind.*, **28** [3] 230 (1937).—A glass tank designed for efficient operation and rapid repairing is described. See *Ceram. Abs.*, **15** [10] 297 (1936). E.J.V.

Fabricating masonry units out of glass. Anon. *Ceram. Ind.*, **28** [2] 146–47 (1937).—Hollow, partially evacuated blocks are formed in cast-iron molds at the Muncie, Ind., plant of the Owens-Illinois Glass Co. Four face patterns are used to obtain decorative qualities, combined with a variation in the light transmission coefficients. Complete production details are given. E.J.V.

Glass-fracture velocity. F. E. Barstow and H. E. Edgerton. *Jour. Amer. Ceram. Soc.*, **22** [9] 302–307 (1939).

Glass insulation for transportation equipment. G. L. Moses. *Transit Jour.*, **83**, 168–69 (1939); *Chem. Abs.*, **33**, 5089 (1939).—High tensile strength and improved dielectric qualities feature glass tape used in place of asbestos or cotton. Forms in which glass insulation are available and the transportation apparatus on which the glass insulation finds its greatest usefulness are listed.

History of the manufacture of colored glass. Anon. *Glashütte*, **69** [14] 257–58 (1939). M.V.C.

Infrared spectrum and structure of glasses. F. Matossi. *Helv. Phys. Acta*, **11** [6] 469–71 (1938); abstracted in *Physik. Ber.*, **20** [5] 609 (1939).—The infrared reflection spectrum of silicates and glasses permits conclusions to be drawn regarding the atomic structure of glasses. Previous investigations (*Ceram. Abs.*, **17** [4] 138 (1938); **18** [1] 17 (1939)) are corroborated. M.H.

Magnetic evidence regarding the state of manganese in glass. S. S. Bhatnagar. *Nature*, **143** [3623] 599–600 (1939).—B. measured the magnetic susceptibilities of borax and phosphate glasses containing manganese. Samples were decolorized with tartaric acid. Susceptibilities of decolorized (reduced) samples of borax glass indicate that the manganese is in the divalent form. In the case of the colored samples, susceptibilities intermediate in value between those for divalent and trivalent manganese were obtained. Results of fluorescence tests on the phosphate glasses indicate the presence of divalent manganese in decolorized (reduced) specimens. Preliminary susceptibility measurements on phosphate glasses indicate complications from probable polymerization of the manganese salts formed. J.L.G.

Relaxation of stresses during the tempering of glasses. A. N. Dauvalter. *Zhur. Tekh. Fiz.*, 9 [9] 782–85 (1939).—The relaxation of stresses during the tempering of glasses was investigated with the aid of a Bezborodov heating polarimeter. Over twenty-five samples of glass were investigated at 5 to 15 different temperatures. The glasses were mostly lime-potash-soda, and some contained up to 6.5% Al_2O_3 and up to 1% Fe_2O_3. At the start of the experiment the value of double refraction in the middle of the glass bars was determined. The electric oven was then heated up to a definite temperature which was kept constant. The experiments were conducted up to P of $1^1/_2$ mμ/cm. so as to include the greater part of the relaxation curve. The results are given in an empirical formula which represents the relaxation curves well. They show that the Maxwell and the Adams and Williamson formulas used in the tempering of glasses are not close enough to experimental results. The following formula was found to approach closely the experimental results: $-dP/dt = (\alpha/\beta)sh\beta P$ where sh is the hyperbolic sine, and α and β are coefficients. It can be shown that α is connected to the viscosity of the glass and related to the absolute temperature by $\log \alpha = n - m/T$. See "Calculating—," *Ceram. Abs.*, **18** [9] 237 (1939). B.Z.K.

Testing medicinal glasses with the narcotin and methyl-red tests. L. Springer. *Sprechsaal*, **72** [16] 198–200 (1939).—Observations from practical experience in making these tests are given. The narcotin test is a cold-water test especially for glasses affected by air weathering, but difficulties are encountered in its use unless the narcotin solution is made of strictly neutral distilled water and the glass is properly cleaned before the test. The methyl-red coarse powder test and the methyl-red surface test are differentiated. Only the former is official now in Germany; it is used for testing ampoule glass with higher requirements than ordinary medicine glass. The grain size of the powder should be limited to 0.3 to 0.5 mm. in diameter. An international commission should take up the uniform regulation of tests. M.V.C.

Use of alkali fluorides in transparent glasses. A. Thurmer. *Ceram. Ind.*, **28** [2] 162–66 (1937).—T. gives a detailed report of experiments on the behavior of alkali-containing fluorine compounds in melts of transparent glasses with respect to the dissociation of the raw materials and the formation of glass. Data include the loss in melting (%), fluorine in glass (%), bubbles per square centimeter, and light-transmission values. E.J.V.

Welding glass to metal. Westinghouse Electric & Mfg. Co. *Steel*, **103** [23] 57 (1938).—A lathe setup with multijet manifolds is used in making metal-to-glass fused joints for X-ray apparatus. The end of a copper tube is machined to extreme thinness and heated in a lathe to a bright red heat by a combination of illuminating gas and oxygen. The glass tubing is then telescoped over

the copper and allowed to fuse to the metal; it is then flame annealed to remove strains. Any glass-metal combination can be fused provided melted glass will wet the metal. Illustrated. H.E.S.

BOOKS AND SEPARATE PUBLICATIONS

5000 Years of Glass. F. ROGERS AND A. BEARD. Frederick A. Stokes Co., New York, 1937. 303 pp. Price $2.50. Reviewed in *Ceram. Age*, **30** [5] 149 (1937); *Mech. Eng.*, **60** [1] 92 (1938).—This popularly written history of glass from the earliest known manufacture to modern practice covers the development of glassmaking processes and glass coloring, with chapters on plain and stained window glass, gas and electric-light bulbs, lenses, and mirrors. Special recent trends and the probable future uses of glass are discussed. F.G.H.

Foreign Production Survey on Flat Glass Products. *U. S. Tariff Commission Rept.*, No. 23; reviewed in *Nat. Glass Budget*, **53** [43] 1, 8, 12, 13, 16; [44] 12, 16 (1938).—The bulk of the world production of flat glass is produced by the U. S., Belgium, Germany, Czechoslovakia, France, the United Kingdom, the U.S.S.R., and Japan. Exports from these countries represent practically the total international trade in such glass. Window glass is the largest item among exports of flat glass. Belgium is the principal exporting country, followed by Czechoslovakia and Germany. Plate glass is exported mainly from Belgium, Germany, the U. S., and the United Kingdom. H.E.S.

Safety Glass for Land Transportation. British Standard Specification No. 857—1939. BRITISH STANDARDS INST., London, June, 1939. Price 2s.—This specification relates to safety glass in automobiles and airplanes. Full details of the tests and the results to be expected are given. 11 illustrations. A.B.S.

Spectrographic Analysis in Great Britain. Edited by A. C. CANDLER. Adam Hilger, Ltd., London, 1939. 80 pp. Price 7s 6d. Reviewed in *Mech. Eng.*, **61** [7] 557 (1939).—The use of spectrographic analysis in the glass industry is discussed. F.G.H.

PATENTS

Antiglare spectacles, etc. W. B. MCCURD. Brit. 508,388, July 12, 1939 (Jan. 3, 1938).

Apparatus for:

Gathering and forming glass. A. F. TREMBLAY (Kent-Owens Machine Co.). U. S. 2,168,833, Aug. 8, 1939 (Nov. 2, 1936).

Making mineral wool. D. C. DRILL (American Rock Wool Corp.). U. S. 2,166,400, July 18, 1939 (Sept. 30, 1937).

Manufacturing blown glass articles. H. E. G. ROWLEY (Soc. á r. l. Jerome & Bonnefoy & Cie). Brit. 508,784, July 19, 1939 (Dec. 4, 1937).

Manufacturing glassware. LOUIS BOUDIN (Soc. Anon. des Manufactures des Glaces & Produits Chimiques de St. Gobain, Chauny & Cirey). U. S. 2,167,290, July 25, 1939 (June 26, 1935).

Tempering glass. J. L. DRAKE (Libbey-Owens-Ford Glass Co.). U. S. 2,166,427, July 18, 1939 (Nov. 4, 1935).

Tempering glass sheets. G. R. FORD, JR. (Libbey-Owens-Ford Glass Co.). U. S. 2,166,348, July 18, 1939 (June 5, 1936).

Chilling media for tempering glass. PILKINGTON BROS., LTD. (Corning Glass Works). Brit. 507,170, June 21, 1939 (Dec. 10, 1937).

Compound reading lens. R. E. FOSDICK. U. S. 2,166,988, July 25, 1939 (June 1, 1936).

Controlling arrangements for the pneumatic operation of glass-feeding and shaping machines. SHEPPEE MOTOR & ENGINEERING CO., LTD., AND S. G. JOWITT. Brit. 509,023, July 19, 1939 (Jan. 10, 1938).

Glare-preventive lens. F. J. HARI. U. S. 2,166,684, July 18, 1939 (June 11, 1936).

Glass building block. W. O. LYTLE (Pittsburgh Plate Glass Co.). U. S. 2,167,764, Aug. 1, 1939 (Sept. 12, 1936).

Glass furnace. ROBERT G. MCLEISH (O'Neill European Machine Co.). Can. 382,947, July 25, 1939 (March 30, 1937). G.M.H.

Glass-to-metal seal. A. W. HULL AND E. E. BURGER (General Electric Co.). U. S. 2,167,482, July 25, 1939 (May 15, 1936; renewed April 15, 1939).—A glass-to-metal seal comprises a glass which contains about 50 to 64 SiO_2, about 29 to 40 B_2O_3, and about 2 to 7% of an alkali material in combination with an alloy consisting essentially of about 39 to 43% nickel with a complementary proportion of iron, the glass and the alloy having thermal-contraction characteristics which substantially correspond at temperatures both above and below the transformation zone.

Glass perforating. W. A. MAHER (Crowe Name Plate & Mfg. Co.). U. S. 2,168,650, Aug. 8, 1939 (March 12, 1938).

Grinding machine. R. S. HINSEY (Libbey-Owens-Ford Glass Co.). U. S. 2,166,356, July 18, 1939 (March 23, 1936).

Installation for the manufacture of sheet glass. SOC. ANON. DES MANUFACTURES DES GLACES & PRODUITS CHIMIQUES DE ST. GOBAIN, CHAUNY & CIREY. Brit. 509,208, July 26, 1939 (Sept. 28, 1937).

Laminated light polarizer. E. H. LAND (Polaroid Corp.). U. S. 2,168,220, Aug. 1, 1939 (Aug. 15, 1936). U. S. 2,168,221, Aug. 1, 1939 (Oct. 14, 1936).

Lens grinding and polishing machine. W. A. LOCKHART (Shuron Optical Co., Inc.). U. S. 2,168,843, Aug. 8, 1939 (Feb. 2, 1937).

Method and apparatus for casting vitreous articles. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 508,295, July 12, 1939 (Feb. 1, 1938).

Method and apparatus for coating vitreous tubing. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 507,187, June 21, 1939 (Dec. 11, 1936).

Method and apparatus for making glass articles. P. R. LUERTZING. U. S. 2,166,871, July 18, 1939 (Oct. 12, 1937).

Method and apparatus for severing molten glass. F. L. O. WADSWORTH (Ball Bros. Co.). U. S. 2,166,563, July 18, 1939 (March 4, 1935; May 29, 1937).

Method and apparatus for treatment of glass, etc. D. I. DU BOIS (Armstrong Cork Co.). U. S. 2,166,428, July 18, 1939 (Aug. 23, 1934; renewed June 22, 1938).

Method of banding articles. H. R. SCHUTZ (Libbey Glass Co.). U. S. 2,167,589, July 25, 1939 (Nov. 6, 1936).

Method and means for forming unbreakable lenses. E. G. LLOYD. U. S. 2,166,215, July 18, 1939 (Dec. 28, 1936).

Method and means for shaping glass. ACHILLE VERLAY (Soc. Anon. des Manufactures des Glaces & Produits Chimiques de St. Gobain, Chauny & Cirey). U. S. 2,167,318, July 25, 1939 (Nov. 23, 1934).

Process and apparatus for hardening glass. G. P. DESPRET (American Securit Co.). U. S. 2,167,294, July 25, 1939 (May 26, 1932).

Producing molten glass free from stones, bubbles, and seeds. ALGEMEENE KUNSTVEZEL MIJ. N. V. Brit. 509,007, July 19, 1939 (Feb. 26, 1938).

Production of roving from a band or lap of glass fibers. SOC. ANON. VETRERIA ITALIANO BALZARETTI MODIGLIANI. Brit. 508,531, July 12, 1939 (Nov. 5, 1937).

Sheet glass and apparatus and method for manufacture. I. O. PEDERSEN AND C. P. BYRNES (Clarence P. Byrnes). U. S. 2,167,905, Aug. 1, 1939 (Oct. 16, 1933).

Tubular incandescent lamp. CLARENCE BIRDSEYE. Can. 382,654, July 18, 1939 (Jan. 25, 1938; in U. S. Oct. 6, 1937). G.M.H.

Structural Clay Products

Brick with a light filler. P. SOLOVYOV. *Keramika*, **1939**, No. 2, pp. 16–17.—Clay brick can be made by adding to the batch a considerable amount of crushed pumice. A disadvantage is the abrasion of press dies. P.B. & E.S.

Brick paving for foundry floor. H. A. MASON. *Dependable Highways*, No. 163, pp. 3–8 (1939).—The advantages of using paving brick as a flooring material for the molding and finishing departments of steel foundries are discussed. Construction details of a floor area of 48,000 sq. ft., requiring 132,000 paving brick, are given. Illustrated. P.S.D.

Choosing materials and methods of construction for the modern building. R. FITZMAURICE. *Jour. Roy. Inst. Brit. Architects*, **44** [15] 779 (1937).—F. describes various types of building failures, including the cracking of cement walls due to thermal expansion or the volume changes caused by changing moisture content, the cracking of stones and tile caused by freezing, the shrinking of precast sawdust-cement concretes, the disintegration of clinker concrete containing unburned coal residues, and the efflorescence of brickwork. Methods of avoiding these and other failures are suggested. See "Principles—," *Ceram. Abs.*, **18** [2] 51 (1939). R.A.G.

Damp and modern brickwork. ANON. *Clay Prod. Tech. Bur. Gt. Brit., Tech. Bull.*, No. 14.—Structural faults, including lateral penetration, are analyzed, and the choice of suitable mortars for various types of brick is discussed. K.W.W.B.

Decline of the mason-architect in England. DOUGLAS KNOOP AND G. P. JONES. *Jour. Roy. Inst. Brit. Architects*, **44** [19] 1004 (1937).—Robert Grumbold (1639–1720) may be regarded as the last great mason-architect in England, although master workmen capable of designing buildings lived after his time. R.A.G.

Determination of the required amount of $BaCO_3$ for the production of unstained brick. MARSCHNER. *Tonind.-Ztg.*, **62** [21] 242–43 (1938).—The method of Seger and Cramer, which consists in adding 1 to 10 ml. of $BaCl_2$ solution to equal amounts of clay in 10 bottles, shaking, filtering, and testing with H_2SO_4, gives results which check well with the chemical analysis. To avoid absorption of barium salts by the clay, the addition of $AlCl_3$ is recommended. W.K.

Factors involved in improvement of clays through p_H control. G. J. BARKER AND EMIL TRUOG. *Jour. Amer. Ceram. Soc.*, **22** [9] 308–12 (1939); see *ibid.*, **21** [9] 324–29 (1938).

Heat transmission through walls. A. F. DUFTON AND H. SHEARD. *Jour. Inst. Heating & Ventilating Eng.*, **5** [50] 82–87 (1937); **6** [67] 360–70 (1938).—Tests with different wall materials in specially built test rooms are described. Results, particularly heat-transmission coefficients, are given. See *Ceram. Abs.*, **17** [10] 330 (1938). J.M.N.

Hidden health. ANON. *Ceramics in Art & Ind.*, No. 2, pp. 37–40 (1939).—The durability of stoneware drainpipe and the importance of this and other sanitary ware in the fight against disease are discussed. A.B.S.

Historical review of monolithic brick pavement. ANON. *Dependable Highways*, No. 163, pp. 9–11 (1939). P.S.D.

Preventing the surface of face brick from soiling. I. YA. SLOBODYANIK, L. A. MELENEVSKIĬ, AND E. V. SOROKA. *Keramika*, **1939**, No. 1, pp. 22–25.—Light-colored brick of high porosity can be kept clean by artificially densifying the surface by subsequently treating it with sodium silicate and calcium chloride solutions. The method has proved satisfactory with samples stored for six months. P.B. & E.S.

Producing brick in structures that move. ANON *Ceram. Age*, **32** [3] 72–73 (1938).—A common and face brick plant operated on the Circle System is briefly described. Illustrated. F.G.H.

Recent French architecture. H. S. GOODHART-RENDEL. *Jour. Roy. Inst. Brit. Architects*, **44** [13] 661 (1937). —The infrequency of solid brick walls and the cost of brick or stone facing above that of rubble are the probable causes of the widespread use of external wall-surface coverings such as plastics, tile, mosaics, terrazzo, etc., in France. R.A.G.

Repair and repointing of existent brickwork. L. W. BURRIDGE. *Clay Prod. Tech. Bur. Gt. Brit., Tech. Bull.*, No. 5 (1937).—Old brickwork was often built without a dampproof course and with a lime mortar. The latter, having a higher porosity than the brick, preferentially absorbs soluble salts from the soil, and the disruptive effects during crystallization are confined to the joints. The use of modern dense cement-sand mortars for repointing reverses this situation and results in damage to the brickwork. Compositions and working data for suitable lime mortars are given. Illustrated. K.W.W.B.

Report of Permanent Committee on simplification of variety and sizes of vitrified paving brick. C. C. BLAIR. *Bull. Amer. Ceram. Soc.*, **18** [8] 306 (1939).

Resistance of brickwork to rain penetration. ANON. *Dept. Sci. Ind. Research, Rept. Bldg. Research Board*, **1938**, pp. 20–21.—A small machine producing imitation rain driven against a wall surface by a 30-mile/hr. wind and tests made with this machine are described. Some panels were penetrated in about 40 min., while others remained dry at the back after 40 hr. No definite conclusions can be drawn. A.B.S.

Re-use of salvaged brick. L. W. BURRIDGE. *Brick Builder*, No. 46, pp. 24–26 (1937); *Clay Prod. Tech. Bur. Gt. Brit., Tech. Bull.*, No. 5 (1937).—B. discusses the use of salvaged brick, especially those of historic interest. Apparent economy and aesthetic appeal are outweighed by (1) poor bond strength, which is necessary for the development of a continuous linkage, due to the loss of capillary activity; the pores of the brick are blocked by the original mortar; (2) contamination during previous use, e.g., by (*a*) soluble soil salts, causing efflorescence, (*b*) tar deposits from the exterior walls of urban structures, (*c*) gypsum from plasters, and (*d*) various mold growths, etc., from storage; (3) irregularity in size and quality, owing to the inevitable mixing of good exterior and second-rate interior brick. Crushed salvaged brick are not suitable as an aggregate for concrete. K.W.W.B.

Testing the strength of brick in the plant. H. HECHT. *Tonind.-Ztg.*, **62** [29] 325–27; [30] 338–40 (1938).—Tests of compressive strength are not easily made in the plant on account of the special shape and high load required. For transverse strength a whole brick can be used and a smaller load is required; roofing tile can be tested on the same apparatus. Formulas for the relation between crushing strength and transverse strength have been calculated but are not always applicable. W.K.

PATENTS

Interlocking building brick or blocks. T. PHEARSON-PRESTCOTT. Brit. 508,283, July 12, 1939 (Dec. 3, 1938).

Machine for producing rusticated brick. R. T. L. SHORROCK. Brit. 508,325, July 12, 1939 (Feb. 16, 1938).

Manufacturing porous building materials. P. MIGLIAVACCA. Brit. 506,949, June 21, 1939 (March 30, 1938).

Refractories

Action of mixtures of coke gas and steam at high temperatures on the refractories of coke ovens. M. W. GOFTMAN. *Koks & Khim.*, **7** [12] 26–28 (1937); abstracted in *Chem. Zentr.*, **1939, I**, 2659–60.—The conclusions of Deschalit (*Ceram. Abs.*, **17** [6] 221 (1938)) concerning the attack of coke-oven gas and steam on oven

refractories are disclaimed, and the stability of the refractories under these conditions is attested. M.V.C.

Andalusite plugs in the casting of steel. P. A. LANDE AND V. S. TRUBENKOV. *Kachestvennaya Stal*, **6** [1] 37–42 (1938).—The authors describe the method of preparing andalusite plugs for casting 15, 30, and 225 tons of fused open-hearth and electric-furnace steels. The composition of andalusite used as raw material was as follows: SiO_2 41.9 to 51, Al_2O_3 + TiO_2 42.5 to 47.5, and Fe_2O_3 2.4 to 4.95%. The plugs were fired at 1380° to 1410°C. Chasov-Yar clay No. 6 was used as binding material. The composition of the plugs after firing was Al_2O_3 47% and lye 2% with a high content of Fe_2O_3. Deformation under load began at 1430°C, and deterioration occurred at 1530°C. Andalusite plugs prepared in the laboratory and in industrial practice by the same process as that used for grog plugs are of high quality. B.E.K.

Combustion of the walls of a carbon tube under the influence of forced diffusion of oxygen. O. A. TSUKHANOVA. *Zhur. Tekh. Fiz.*, **9** [4] 295–304 (1939).—Experimental data are given on the effect of hydrodynamics upon the combustion intensity and characteristics of gas formation during the combustion of a cylindrical C tube. Air was preheated to 700° to 800° and admitted to the tube at rates of 2 to 50 liters per min. The combustion gases were cooled to prevent the oxidation of CO and were then analyzed. The amount of C consumed was determined from air consumption and gas analysis. Both laminar and turbulent regions of combustion could be distinguished, depending upon the conditions of gas flow. In turbulent combustion, the intensity increased with increased oxygen addition to the C surface and also with the outflow of CO from the combustion zone. The outflow of large amounts of CO starts when the ratio of the length of the oxygen zone to the average gas speed is less than $1:10^{-3}$. B.Z.K.

Crucible furnaces. R. H. STONE. *Trans. Amer. Foundrymen's Assn.*, **46** [2] 405–12 (1938).—The tilting furnaces have been greatly improved in ease of operation, efficiency, and applicability. For rolling-mill practice, they are now made to tilt about the end of the lip as an axis so that metal may be poured directly into ingot molds in the train as they successively come up to the pouring station. The tilting furnaces are commonly used in sizes of 375-lb. and 1200- to 1500-lb. capacity. The working conditions are very good, the operation of burners is largely under automatic control, and the use of the same crucible for both melting and pouring results in rapid, efficient operation at minimum cost. For greater flexibility, a combination of tilting and lift-out furnaces is installed. Illustrated. H.E.S.

Cupola operation. D. J. REESE. *Trans. Amer. Foundrymen's Assn.*, **46** [1] 173–92 (1938).—One of the most important factors in cupola operation is the amount of coke on the bed charge. The use of the smallest size of cupola consistent with production demands is stressed. R. discusses fuel-burning rates, melting rates, normal operating conditions, wind-pressure requirements, and coke and metal charges, giving formulas and examples. Tuyère performance, blower types, gauges, and metering devices are pointed out. R. also discusses the control of moisture in the blast, preheated air, and factors related to the temperature of the iron at spout and at pouring. **Discussion.** DEANE ET AL. *Ibid.*, pp. 193–94 (1938). H.E.S.

Destruction of coke-oven linings. A. P. NIKOLAIEV AND A. S. SHLEIMOVICH. *Koks & Khim.*, **8** [1] 30–34 (1938); abstracted in *Chem. Zentr.*, **1939, I,** 2659.—The cause of the destruction of coke-oven linings at the Dneprodshershinsk coke chemical factory and alterations made in the furnace construction are discussed. M.V.C.

Desulfurizing. R. S. MCCAFFERY. *Steel*, **103** [11] 46–49 (1938).—Better blast-furnace operation may be obtained by desulfurizing in the ladle. Ores with high sulfur content are handled successfully by desulfurizing with a compound containing soda ash, limestone, and fluorspar. The chief desulfurizing reagent is sodium. The process is best carried out in the ladle, which is provided with a cover in order to maintain as high a temperature as possible. H.E.S.

Electrocast refractories: I. K. SEKI. *Repts. Imp. Ind. Research Inst., Osaka, Japan*, **18** [8] 131 pp. (1937).—S. studied the Al_2O_3–SiO_2, Al_2O_3–MgO, MgO–SiO_2, and Al_2O_3–MgO–Cr_2O_3 systems. Batches were melted in the small electric-arc furnace and cooled. P.C.E., spalling tendency, and thermal expansion were determined. Resistance to basic open-hearth slag, acid open-hearth slag, borosilicate glass, and soda-lime glass was investigated. Refractories of the Al_2O_3–MgO–Cr_2O_3 system are resistant to glasses but can not be used in a glassmelting furnace because they contain Cr_2O_3. Refractories which contain high alumina are suitable for glass furnaces and acidic open-hearth furnaces; refractories of the Al_2O_3–MgO and Al_2O_3–MgO–Cr_2O_3 systems are excellent for basic open-hearth furnaces. The microstructure was also studied. Y.K.

Grain-size distribution of refractories. ADOLF MÖSER. *Tonind.-Ztg.*, **61** [97] 1069–71; [98] 1083–85 (1937).—M. attempts to find a relationship between the grain-size distribution of the grog and the permeability of the body. On 16 systematically varied mixtures of grog, the weight per volume, percentage of voids, and the rate of flow of water through a column of the mixture were determined. Bodies using these mixtures were made up, and their absorption and permeability were measured. M. arrives at a factor, *Mk*, which is the product of the percentage of voids and the surface factor divided by the mean diameter of the pores and which is proportional to the permeability of the body. W.K.

Highly refractory material from dunite raw material; its technical properties and use. YA. I. DOLITSKIĬ. *Sovet. Met.*, **10** [1] 17–24 (1938); *Chem. Abs.*, **33,** 5142 (1939).—In one investigation, dunite waste rock was used; it was composed principally of olivine and serpentine with a small content of magnetite, chromite, etc.; the specific gravity was 2.60 to 2.80, mechanical strength was 750 to 1350 kg./sq. cm., and refractoriness was 36 to 37 P.C.E. The thermal expansion coefficient of dunite fired at 20° to 750° was about 1.0×10^{-6}, the thermal expansion curve being nearly a straight line. It and brick made from it were very resistant to the action of slags as compared with quartzite and silica brick. The mass was worked up with pans, pressed at 400 to 750 kg./sq. cm., and fired at 1550° (better at 1600° to 1620°). The brick had a shrinkage of 0.5 to 4.5% (depending upon the composition of the batch), a specific gravity of 2.45, an apparent porosity of 25 to 28%, a mechanical strength of 160 to 340 kg./sq. cm., and a refractoriness of 37 to 38 P.C.E.; the beginning of deformation under load (2 kg./sq. cm.) occurred at 1620° to 1660° and beginning of collapse under load occurred at 1720° to 1730°. Brick made under semiplant conditions showed even higher values. In an investigation in another laboratory, dunite composed of 36% olivine and 64% serpentinite (a typical serpentinized dunite) was used. Fired Satka magnesite (a high refractory about 1920°) chrome ore and plastic clay were used as additions. Test pieces were fired at 1500°. The crushing strength at high temperatures was greatest with 25% magnesite; the temperature of the beginning and end of deformation increased considerably, and the softening interval reached its highest value. An increase of clay content from 0.75 to 2 to 3% was accompanied by a small (10° to 20°) decrease of the deformation temperature. Up to 1.25% clay increased the specific gravity of air-dried samples, increased the crushing strength and the shrinkage, and decreased the apparent porosity and water absorption. Increasing the chromite and magnesite content increased the temperature of beginning of deformation under load. In masses containing 15% magnesite, an addition of about 1% clay was sufficient, and in those containing 25% it was superfluous. Masses of low porosity were obtained by adding 20% chromite in addition to 15% magnesite. Higher-grade brick were obtained by increasing the firing temperature from 1500° to 1600°.

Manufacture of Dinas brick with increased resistivity. I. S. SMELYANSKIĬ. *Stal*, **8** [4] 76–78 (1938).—One of the principal methods of increasing the thermal resistivity consists in preparing Dinas brick from a mass with a large granulated composition and a reduced content of lime. Brick prepared from such a mass, called electrodinas, were not destroyed by firing tests. The mass of electrodinas contains grains of quartzite of 8 mm. and about 30 to 35% of grains of 0.5 mm. Because of the presence in ordinary Dinas brick of 50 to 60% of small grains and about 3% of lime and other oxides, about 19% of glass is formed in firing which shows poor heat resistivity of these brick. Electrodinas contains about 1.6% of lime and a maximum of 35.8% of grains up to 0.5 mm. The composition of electrodinas is quartz 15, cristobalite 17, tridymite 66, and glass about 5.8%. S. describes the results of tests of electrodinas brick in the roof of an electrical furnace of the Elektrostal works. During the fusion, boiling, and refining of metals, visible fissures and breakage of the brick were not evident. Electrodinas brick in the roof of an 8-ton electrical furnace withstood 43 fusions. The minimum mechanical strength of electrodinas is double that of ordinary Dinas brick, and electrodinas possesses a higher heat resistivity. To raise the refractoriness of Dinas to 1750°C, S. prepared a Dinas brick with a siliceous binding and without lime. See "Silica—," *Ceram. Abs.*, **18** [5] 130 (1939). B.E.K.

Nonferrous melting requires excellent furnace operation. N. K. B. PATCH. *Foundry*, **65** [7] 25–26, 66 (1937).—The installation and maintenance of refractory linings in various types of nonferrous metal melting furnaces are discussed in detail. Illustrated. F.G.H.

Open-hearth control. M. J. BRADLEY. *Steel*, **103** [9] 34–36, 60 (1938).—Automatic controlling equipment for combustion control, pressure control, automatic reversing, and checker chamber temperature measurement, as well as temperature measurement before and after going through the waste-heat boiler, enables many furnaces to produce a better quality steel. The savings effected by automatic instrument control average 9% in tonnage, 12% in refractories, and 8% in fuel. H.E.S.

Progress in refractories in 1937. ANON. *Steel*, **102** [3] 42–44 (1938). H.E.S.

Quartz-glass refractories for the roof of open-hearth furnaces. S. P LOGINOV AND V. A. NAICHUK. *Novosti Tekhniki*, **1938**, No. 24, pp. 15–16.—The possibility of using quartz glass as a refractory material was studied. Laboratory tests of specimens of quartz glass prepared by the authors show that (1) the refractoriness is about 1750° to 1770°C; (2) the beginning of deformation under load of quartz glass occurs at 1660°C, and that of quartz transformed to cristobalite, at 1750°C. Brick prepared from quartz glass were used for the roof of an open-hearth furnace of the Kramatorsk metallurgical works. After 116 fusions of metals, 50% of the quartz glass was transformed to cristobalite, and the fused brick showed practically no deterioration. The slag had not penetrated into the brick. B.E.K.

Refractories for foundry ladles. C. E. BALES AND A. R. BLACKBURN. *Trans. Amer. Foundrymen's Assn.*, **46** [1] 163–70 (1938).—The use of special firebrick shapes for pouring-ladle service is described. Pouring-ladle brick prevent slag particles from getting into the molds. The use of ladle bottom tile overcomes "boiling" and gives a jointless bottom; it can be installed more economically than firebrick bottoms. Plastic ramming mixes for use in desulfurizing ladles are also described. **Discussion.** CARMODY ET AL. *Ibid.*, pp. 170–72. H.E.S.

Refractory cost may be cut. Nonferrous foundry may profit through study of melting problem. N. K. B. PATCH. *Foundry*, **66** [3] 37, 83 (1938).—The selection of the proper type of refractory for various nonferrous foundries is briefly discussed. Illustrated. F.G.H.

Refractory service increased through study of problem. S. M. SWAIN. *Foundry*, **66** [7] 29–30, 78 (1938).—S. discusses the selection of refractories for service in a cupola and gives a detailed consideration of the various destructive forces which affect the life of refractories. F.G.H.

Softening and fusion of refractories. A. KUPFERATH AND EDMUND R. THEWS. *Can. Metals Met. Inds.*, **2**, 82–85 (1939); *Chem. Abs.*, **33**, 5143 (1939).—Causes of the softening of refractories in metallurgical furnaces are noted, and suggestions for their correction are reviewed.

Strength of channel brick. A. N. KOSSOGOVSKIĬ. *Uralskaya Metallurgia*, **1937**, No. 1, pp. 43–45.—K. discusses the problem of consistent composition and quality of channel brick and concludes that two standards should be established: (1) for calm steel, with an Al_2O_3 content of about 25%, and (2) for boiling steel, with an Al_2O_3 content of not less than 35%. B.E.K.

Thermal and electrical conductivities of carbon and graphite at high temperatures. R. W. POWELL AND F. H. SCHOFIELD. *Proc. Phys. Soc.* [London], **51**, Part 1 [283] 153–72 (1939).—Experimental results are given for a variety of carbon consisting of 80% of petroleum coke combined with 20% lampblack at temperatures up to about 2000°C and for Acheson graphite up to about 2700°C. Evidence for the graphitization of carbon is obtained from the fact that the results for this material at the highest temperatures tend to conform to those for graphite. At normal temperatures the Lorenz functions, $K\rho/T$, of carbon and graphite are about 17 and 200 times as great, respectively, as the value normally obtained for metals. These values, however, decrease rapidly with increase in temperature, and at 1700°C the Lorenz functions of both materials are only about 4 times as great as those of metals. Five tables, eight diagrams. L.E.T.

Thermal stability of firebrick: II. B. YA. PINES, V. YA. BILYK, AND G. P. KUSHTA. *Zhur. Tekh. Fiz.*, **9** [1] 71–87 (1939).—Magnesite firebrick having different binders, such as forsterite, spinel, etc., were tested. The mechanical properties were determined and correlated with the thermal stability. The thermal stability was determined with the aid of the formula previously given. The structural changes involved with increasing thermal stability were also studied. The samples were subjected to petrographic analysis, and the results are tabulated. Magnesite and chrome-magnesite firebrick containing additions of BaO, SrO, TiO_2, Cr_2O_3, B_2O_3, Zr_2SiO_4, and liquid glass were tested. Results show that the low thermal stability of ordinary magnesite firebrick is due to the presence of vitreous shells around the grains which hinder the plastic deformation of periclase crystals and which produce, in the course of heating, additional local stresses due to heterogeneity. Increased thermal stability of magnesite firebrick is due to the elimination of vitreous layers and the formation of a crystalline binder which cements the grains and has some plasticity. This binder consists of forsterite and spinel crystals possessing expansion coefficients very close to that of periclase. These structural changes result in a decrease in the apparent modulus of elasticity of about 10 times and a decrease in tensile and shear strengths. The same structural changes and corresponding mechanical and thermal stability characteristics may be produced in the magnesite and chrome-magnesite firebrick containing various additions. This is due apparently to the same general mechanism of the elimination of vitreous shells from the grains. For Part I see *Ceram. Abs.*, **18** [9] 246 (1939). B.Z.K.

Variation with temperature of the electrical resistance of carbon and graphite between 0° and 900°C. L. J. COLLIER, W. L. STILES, AND W. G. A. TAYLOR. *Proc. Phys. Soc.* [London], **51**, Part 1 [283] 147–52 (1939).—The variation with temperature of the electrical resistance of specimens of amorphous carbon and of Acheson graphite has been determined for temperatures between 0° and 900°C on rods 57 cm. long and 1.6 cm. in diameter, heated in vacuum. The results obtained are compared with those recorded by other investigators. The work is to some extent complementary to that of Powell and Schofield (see this issue), who determined the thermal and electrical conductivities of the same materials between 75° and 2500°C. Two samples of Acheson graphite showed minima of resistance at about 390° and 430°C, respectively. L.E.T.

BOOKS

Effect on the Porosity After Firing of an Addition of Powdered Silica to a Refractory Clay, a Marly Mix, and a Marl. V. BODIN AND P. GAILLARD. Inst. Céramique Française, Paris. 46 pp. Reviewed in *Verre & Silicates Ind.*, **10** [15] 177 (1939).—Experiments were made to ascertain whether the addition of powdered silica facilitates the obtaining of stoneware from ceramic pastes and diminishes the porosity of building materials. By adding powdered silica with a mix of marl to a refractory clay, a stoneware can be obtained at lower temperatures than usual. Marls alone do not effect any improvement. In certain cases it is possible to reduce the porosity of building materials. M.V.C.

Modern Furnace Technology. H. ETHERINGTON. J. B. Lippincott Co., Philadelphia, 1938. 524 pp. Price $12.00. Reviewed in *Mech. Eng.*, **61** [1] 81 (1939).—E. explains the scientific principles underlying the various phases of modern furnace design and operation and their application in achieving operating improvement. Combustion, gas flow, heat transfer, and physicochemical theories are covered, and there is a long chapter on refractory materials. Diagrams and tables of practical data are included to assist in the practical application. F.G.H.

PATENTS

Alumina. AXEL S. BURMAN. Fr. 49,022, Oct. 14, 1938; *Chem. Abs.*, **33,** 5137 (1939). Addition to 822,430 (*Ceram. Abs.*, **17** [11] 357 (1938)).—An evaporation apparatus having walls made of synthetic resin unattacked by acid or enameled metal is used for the salt solution. The mother liquor from the evaporation is returned to the solution to increase its content of ferrous salts and other impurities before it is treated to recover acid.

Alumina. JEAN C. SÉAILLES. Fr. 829,794, July 6, 1938; *Chem. Abs.*, **33,** 1454 (1939).—Crude anhydrous Ca aluminate is dissolved in water, the insoluble impurities are removed, and Al_2O_3 and CaO are precipitated. The precipitate is treated with Na_2CO_3 to cause the Al_2O_3 to pass into solution as aluminate, and the $CaCO_3$ is separated. The $NaAlO_2$ solution is treated with CO_2 to precipitate Al_2O_3 and re-form Na_2CO_3. Fr. 49,066, Nov. 7, 1938; addition to 829,794.—The precipitates containing $CaCO_3$ and corrected by the addition of lime or $CaCO_3$ are calcined above 1300° for rapid firing or at 1000° to 3000° for slower firing. Fr. 49,122, Nov. 7, 1938; addition to 829,794.—The precipitates from the aqueous solution of Ca aluminates are introduced first into the hot Na_2CO_3 lye, and, after a period of mixing, the lime is introduced. In Fr. 49,187, the precipitates are calcined so as to transform Al_2O_3 therein into Ca aluminate.

Dental investment or refractory material. E. M. PROSEN (Nobilium Products, Inc.). U. S. 2,152,152, March 28, 1939 (July 28, 1937).

Effecting the alkaline decomposition of bauxite. VEREINIGTE ALUMINIUM-WERKE A.-G. Brit. 506,885, June 21, 1939 (Oct. 13, 1937).

Electric furnace roof ring. W. E. MOORE (Pittsburgh Research Corp.). U. S. 2,166,964, July 25, 1939 (June 7, 1937).

Furnace lining heat-treating apparatus. WILLIAM E. MOORE AND WILLIAM B. WALLIS (Pittsburgh Research Corp.). Can. 382,949, July 25, 1939 (Oct. 23, 1937). G.M.H.

Manufacturing ceramic and refractory articles. A. P. DE SANNO, JR. Brit. 506,879, June 21, 1939 (June 17, 1938).

Preparation of aluminum oxides. C. TONIOLO AND AZOGENO SOC. ANON. Brit. 508,911, July 19, 1939 (June 24, 1938).

Terra Cotta

Ceramic drum liquid meter to check the efficiency in vinegar factories. H. WUESTENFELD. *Siemens-Z.*, **19** [5] 210–12 (1939).—W. describes a drum liquid meter which measures the quantities of raw material and vinegar in vinegar factories. The efficiency is very high. Glazed porcelain is used for the drum and brown stoneware is used for the casing. Illustrated. J.M.N.

Ceramics in modern industry. ANON. *Ceramics in Art & Ind.*, No. 2, pp. 41–50 (1939).—Stoneware pipes for chemical manufacture and paper mills, jugs for the chemical industry, a perforated stoneware drum for picking light castings, acid-resisting filtering disks and tile, filter candles, and electrical insulators for electric railways are dealt with. 12 illustrations. A.B.S.

Clay in the service of building. ANON. *Ceramics in Art & Ind.*, No. 2, pp. 29, 36 (1939).—The use of glazed terra cotta in modern English buildings is discussed. The best of this terra cotta is fired at 1250°C with the result that the body and glaze are perfectly fused together, the ware is highly vitrified, and crazing is reduced to a minimum. 13 illustrations. A.B.S.

Heat losses through tiled roofs. H. E. BECKET. *Jour. Inst. Heating & Ventilating Eng.*, **4** [43] 313–17 (1936); **5** [53] 236–39 (1937); **6** [70] 540–42 (1938).—B. describes tests with different types of tiled roofs and recommends the proper coefficients of heat transmission. J.M.N.

Insulation. D. H. SMITH. *Jour. Inst. Heating & Ventilating Eng.*, **5** [59] 527–34 (1938).—S. reviews theoretical problems and describes the characteristics of several heat-insulating materials. Noise insulation is also described. J.M.N.

Lightweight and insonorous materials. V. CHARRIN. *Argile*, No. 195, pp. 1–3 (1939).—Kieselguhr as a lightweight building material and its insulating and soundproofing properties are discussed. The coefficient of thermal conductivity of kieselguhr is compared with that of other insulating materials. M.V.C.

Observations on glazes for roofing tile and face brick. ANON. *Tonind.-Ztg.*, **62** [53] 575–76 (1938).—Fritting of all or part of the constituents of the glaze is recommended when the kiln atmosphere is detrimental to the glaze or when it is desired to lower the finishing temperature or to reduce crazing. W.K.

Old roofing tile. O. DRÖGSLER. *Tonind.-Ztg.*, **62** [31–32] 351–52 (1938).—Old roofing tile, some of which were in place over 500 years, almost met present standards of breaking strength. The exposed part was much denser and in some cases stronger than the part that had been covered. W.K.

Producing facing tile with a leadless, tinless enamel. G. K. SERGEEV AND K. V. TROFIMOV. *Keramika*, **1939,** No. 2, pp. 25–28.—The batch for tile consists of potter's clay and marl in the ratio 1:1. The frit is composed as follows (by weight): metalline Sb 5, KNO_3 6, Na_2CO_3 7, crystalline B_2O_3 7, quartz sand 30, feldspar 35, kaolin 9, chalk 1.5, $MgCO_3$ 0.5, ZnO 1, glass breakage 2, and porcelain breakage 2 parts (total, 113 parts). The acidity of the enamel was 1.85; the volume expansion coefficient was 276.10. Sb and one half of the kaolin are added to the frit mill; otherwise an incomplete opaqueness is obtained. The firing must be undertaken in a feebly oxidizing or neutral medium and at a high rate of temperature rise, the final temperature attaining 960° to 980°. Deviations from the standard composition of the batch are easily permissible, i.e., substitution of pegmatite for feldspar, increase of Na_2O instead of KNO_3, and deficiency of ZnO or $MgCO_3$. Metalline Sb can be replaced by coloring oxides (Cr_2O_3, etc.) to obtain high-grade colored facing tile. P.B. & E.S.

Tile for acid-resisting tanks. ANON. *Chem. Age* [London], **41** [1047] 71; [1048] 89 (1939).—Refractory ceramic sandstone tile of two special designs is used, the shapes being such that any stress on the wall, no matter in what direction, is transformed into a compression stress, thus avoiding any strains on the cement used in the con-

struction. One of the shapes resembles a dumbbell with sloping instead of rounded ends and of such dimensions that when two of these blocks are placed at right angles the space between them is a cube which can be filled completely by the second shape. When a tension is introduced at one end of an element, the section at the end of the "dumbbell" causes a pressure on the small cubes filling the interstices. This compression is transmitted to the surrounding tile as a compression strain, so that the only tension possible is within the body of the long tile. The tile themselves are of maximum density and minimum porosity. The coefficient of expansion is less than 0.004 at 1000°C, and the tile are capable of resisting temperatures from 1700° to 1800°C. They have a tensile strength of 45 kg./sq. cm., and the compressive strength of strains is 2 tons/sq. cm. These tile are of the Zeta type of construction. A.B.S.

Tile for filtration purposes. ANON. *Chem. Age* [London], **41** [1045] 26 (1939).—The customary sizes of tile in England are 10 x 9 x $2^1/_2$ in. and 9 x 9 x 2 in., but tile 18 x 12 x $2^1/_2$ in. are used by some firms. They are made almost wholly of silica graded to give a maximum porosity as follows:

B.S.S. sieve	(%)
+5	15.16
+16–5	22.76
+30–16	3.11
+60–30	3.13
+100–60	12.43
+200–100	22.96
-200	20.45
	100.00

The tile have tongue-and-groove joints and flues on the lower face. The porosity is about 31% as compared with 24% for ordinary filter tile, and the specific gravity is about 2.35. Higher porosities are obtained by adding sawdust or other combustible material to the raw silica; the combustible material burns out in the kiln and leaves pores in its place. This method is, however, seldom used for filter tile. Amberlite Super tile are made of calcined kaolin and a ceramic bond. They weigh only 48 lb./cu. ft. but have a cold crushing strength of 270 lb./sq. in. and a porosity of 60 to 65%. Accurate grading of the raw material is essential. These tile can be sawn to any shape. A.B.S.

Tile glazes using various opacifiers. L. STUCKERT. *Ber. Deut. Keram. Ges.*, **20** [5] 215–26 (1939).—S. discusses opacifiers for tile glazes, giving specific ceramic formulas for typical glazes. Cerdioxide as an opacifier, supplied by the Deutsche Gold- and Silber-Scheideanstalt of Frankfurt, is discussed; it is particularly advantageous in providing a white opaque glaze. A mill addition of 2.5 to 3% results in 84.6 to 88.5% opacity. A bibliography is given. C.H.R.

Tripoli roofing tile. M. N. KOSHURNIKOV. *Keramika*, **1939**, No. 3, pp. 33–39.—Tripoli of the following mean composition was used: SiO_2 77.37, TiO_2 0.82, Al_2O_3 10.04, Fe_2O_3 5.04, CaO 1.05, MgO 0.67, SO_3 0.095, loss on ignition 4.12, specific gravity 2.51. Laboratory and plant investigations showed that the tile obtained, in regard to its technical characteristics, is a high-grade roofing material equal to clay tile and superior to it because of its lower weight. This superiority is not influenced even by its higher water absorption (30% instead of 15%) as it gives a lighter roofing even when fully saturated with water. Tests on glazing the tile obtained with raw and fritted glazes gave unsatisfactory results. P.B. & E.S.

Whiteware

Adaptability of the coefficient of spalling resistance to the calculation of glazes and enamels. L. M. BLYUMEN. *Keramika*, **1939**, No. 2, pp. 38–43.—Tests conducted with low-melting glazes give evidence, though not conclusively, that the suggested use of the Winkelmann and Schott formula may be expedient. P.B. & E.S.

Classification of ceramic dinnerware. ARTHUR S. WATTS. *Bull. Amer. Ceram. Soc.*, **18** [8] 314–15 (1939); see *ibid.*, **17** [7] 295–96 (1938).

How surface characteristics affect strength of ceramic materials. D. H. ROWLAND. *Ceram. Ind.*, **28** [3] 212–18 (1937).—The complete absence of ductility in ceramic materials means that strength is to a great extent dependent upon surface conditions. Failures in ceramic ware start at the surface and progress inward through the body until they reach another exterior surface. R. discusses unglazed porcelain, glazed porcelain, crazing from mechanical shocks, glaze in tension or compression, effect of compressive stress, method of determining the stress in a glaze, mechanical strength of different porcelains and glazes, and the practical application of the glaze principle and shows that variations in glaze fit may affect the strength of porcelain 200 to 300%. E.J.V.

Physical chemistry in porcelain manufacture. WILLARD J. SUTTON. *Ceram. Age*, **31** [5] 145–47, 157–58 (1938).—The properties of the raw materials used in the manufacture of porcelain are briefly described, and the reactions which take place upon firing are discussed. Illustrated. F.G.H.

Radiators made from porcelain. ANON. *Rundschau Deut. Tech.*, **19** [28] 10 (1939).—Due to the shortage of certain metals in Germany, the building of radiators from hard porcelain instead of cast iron is proposed. The thermal efficiency is slightly better; the price is somewhat higher but no repainting is necessary. J.M.N.

Strains in glazes as influenced by reaction between glaze and body. A. DIETZEL. *Ber. Deut. Keram. Ges.*, **20** [5] 245–47 (1939).—A thin section of a glazed body shows, upon microscopic examination, that a crystalline separation takes place at the interface. These crystals were new in nature and showed definite evidence of reaction between glaze and body. This interface crystal zone has a thermal expansion coefficient between that of the glaze and the body. C.H.R.

Trends in porcelain. S. J. MCDOWELL. *Ceram. Age*, **33** [1] 10–11, 15 (1939).—The factors which affect the mechanical, thermal, electrical, and chemical properties of porcelain bodies are briefly reviewed. The general trend in the composition of various types of porcelain bodies has been toward a decreased clay content, an increased content of nonplastic materials, and an elevation of the maturing temperature during firing. Most of the spark-plug bodies have a mullite or zircon base. In the field of heat-shock resistant bodies, the recent use of talc in sagger bodies has publicized the cordierite type of body which is produced by the addition of talc or magnesia to clay and flint. There is an apparent trend toward bodies of the cordierite type with additions of other materials to make them more dense and more refractory. F.G.H.

Whiteware body preparation may soon be simplified. ANON. *Ceram. Ind.*, **28** [5] 426–31 (1937).—An electrical porcelain body containing 17% moisture was mixed for 6 min. in a Lancaster mixer, the nodules were broken up in a pulverizer, and the mixed body was pressed, dried, and fired in the usual way. The finished product was comparable with that made from materials processed in the usual way. Mixing for 6 min. produced a body comparable with that run through a standard filter-press process and then aged for 24 hr. The mixing principle employed is described in detail. Additions of up to 1% bentonite gave a dry strength 58.8% higher than that obtained with the regular body. Fired strength was increased 27.4%, and absorption was lowered 16.3%. E.J.V.

SEPARATE PUBLICATION

Physical Properties of Commercial Dinnerware. JOHN H. KOENIG. *Ohio State Univ. Eng. Expt. Sta. Bull.*, No. 101, 67 pp. (May, 1939).—K. conducted this research to (1) obtain fundamental data on the ware, (2) allow individual manufacturers to compare their ware with the average, and (3) obtain material to serve as a reference on testing. Representative specimens were obtained from (A) 22 manufacturers of semivitreous dinnerware and (B) 8 manufacturers of hotel china. Other factors studied were translucency, microtexture of glazes, carbon content of plates, viscosity-temperature characteristics of glazes, the ring emitted (pitch and decrement), and fatigue failure. An appendix gives a review of the literature on testing dinnerware. W.D.F.

PATENTS

Artificial teeth and method and means of making. DENTAL RESEARCH CORP. Brit. 508,204, July 12, 1939 (Dec. 28, 1936).

Ceramic body and method of making. S. J. MCDOWELL (General Ceramics Co.). U. S. 2,168,230, Aug. 1, 1939 (Sept. 2, 1937).—A fired ceramic body characterized by a dielectric power factor of not more than 0.05% comprises talc and nonalkali metallic oxides including antimony oxide.

Clayworking machine. F. M. KINNARD. U. S. 2,167,386, July 25, 1939 (Sept. 10, 1937).

Electric insulators of the strain type. L. A. CHAPMAN. Brit. 508,550, July 12, 1939 (Dec. 31, 1937).

Seals between the ceramic and metal parts of potheads and like electrical fittings. STANDARD TELEPHONES & CABLES, LTD., T. R. SCOTT, AND L. A. C. POOLEY. Brit. 508,693, July 19, 1939 (Jan. 4, 1938).

Spark plug. A. C. HASTINGS, JR. U. S. 2,168,206, Aug. 1, 1939 (Feb. 11, 1938).

Water closet. J. M. TEAHEN. U. S. 2,166,573, July 18, 1939 (Feb. 7, 1938).

Equipment and Apparatus

Adapting miniature cameras to petrographic photomicrography. P. S. DEAR. *Jour. Amer. Ceram. Soc.*, 22 [9] 279–81 (1939).

Apparatus for agitating small volumes of liquid at constant temperature. R. G. WILLCOCKS. *Jour. Soc. Chem. Ind.* [London], **57** [7] 249–50 (1938).—A new machine is designed to shake stoppered or unstoppered tubes in a thermostatically controlled bath in the open laboratory, thus eliminating an incubator. Illustrated. G.R.S.

Automatic air regulation in brick driers. K. SPINGLER. *Tonind.-Ztg.*, **61** [89] 989–91 (1937).—S. discusses the general principles of the regulation of the temperature and humidity of the air in the drier by mixing the hot kiln gas with the recirculated air. The working of automatic controls is described. See "Air—," *Ceram. Abs.*, **18** [2] 55 (1939). W.K.

Closed-circuit grinding of cement raw materials at Leeds. T. B. COUNSELMAN. *Amer. Inst. Mining Met Engrs. Tech. Pub.*, No. 1096; *Mining Tech.*, **3** [4] 16 pp. (1939). W.D.F.

Control and evaluation of temperature by colorimetry and fluorometry. M. DÉRIBÉRÉ. *Argile*, No. 186, pp. 3–7 (1938).—Colorimetric measurements, though without great precision, are a simple and valuable means of controlling and evaluating temperature. They are well known to kilnmen and burners in ceramics and metallurgy and deal with the succession of tints taken by iron or other heated substances as a function of the heating temperature. Another method for colorimetric measurements is based on the fact that the enantiotropic transformation of certain simple or double salts of heavy metals makes them change color at definite temperatures. These paints are applied on switchboards, ball bearings, auto radiators, drying chambers, and on machines for protection. The double salt $Cu_{2}I_{2}$, Hg_{I_2} is commonly used; it is scarlet to 60°C and turns chocolate brown from 60° to 70°C. The double salt $Ag_{I}\cdot Hg_{I_2}$ is yellow to 90° and turns carmine red from 90° to 100°C. Mixtures can also be used, e.g., 25% copper iodide Cu_{I_2} with 15% Hg_{I} which turns from vermilion red to black. These salts are used in the form of paints ground with linseed oil. On cooling, they assume their original color. When a permanent change of color is required, dioxide of lead, which turns yellow, or a mixture of lead sulfide and dioxide of barium, which turns white, is used. By incorporating these indicator salts in cellulose acetate and making foils, the sheets can be glued where the temperature is to be supervised. To avoid exceeding a temperature limit, an alarm operated by a photoelectric cell with a selective filter can be attached. Another system of colorimetry uses the phenomenon of thermoluminescence emissions of substances when heated. Thermoluminescence is fugitive and irreversible, is produced only once in a body, and must be replaced after each emission. The object to be fired can be coated for control of the firing temperature. Certain fluorites emit a succession of varied luminous colorations when heated: orthose gives blue, albite gives green, and limes and marbles give orange thermoluminescence. Quinine sulfate and cinchonidine sulfate give a beautiful blue at about 150°C which is a chemicoluminescence caused by high temperature, while fluorites, feldspars, and calcites are thermophotoluminescent, i.e., phosphorescences do not appear except at a certain temperature which must be determined in each case. Some fluorescent variations can be retained, serving as a new and curious application of Wood's light. M.V.C.

Counting samples taken with the impinger. CHARLES R. WILLIAMS. *Jour. Ind. Hyg. & Toxicol.*, **21** [6] 226–30 (1939).—A new procedure for counting Greenburg-Smith impinger samples is proposed. It involves the use of a higher magnification eyepiece than that which is now being used, together with a new type of counting cell. Results check with those determined by the standard method, and there are greater speed of counting, lack of glare, greater visibility of particles without introducing more particles, shorter settling time, and elimination of the eyepiece micrometer and tube-length adjustment. E.J.V.

Determination of the specific surface of powders: I. P. C. CARMAN. *Jour. Soc. Chem. Ind.* [London], **57** [7] 225–34 (1938).—A study was recently made of fine particles, i.e., those formed by ordinary processes of comminution and passing a 100-mesh sieve, with a lower size limit of about 0.1 μ. Methods of determining particle size and size distribution in a powder have been greatly elaborated, but the evaluation of the specific surface of fine powders has been accorded little attention, although, in most cases, it is more important than particle size. For instance, coal is pulverized to present a large surface to combustion, cement is finely ground because the completeness and rapidity of setting will increase with the specific surface, a silica particle in the lung will dissolve more rapidly as the specific surface is greater, and a fine powder used as a filler for plastics imparts strength chiefly by virtue of its large specific surface. The theoretical work done in grinding must be related to the increase in specific surface. A new method is suggested for obtaining the specific surface of sands and fine powders. In the method, the permeability of a small sample to a liquid of known viscosity is measured, and, from this, the specific surface is calculated, using the equation $S_0 = 14\sqrt{\frac{1}{k_v} \times \frac{\epsilon^3}{(1-\epsilon)^2}}$, where v = kinematic viscosity of the liquid, k = the permeability, ϵ = the porosity of the material, and S_0 = the specific surface. The method is not affected in simplicity or accuracy if the powder contains mixed sizes of particles and particles of irregular shape. For Part II see *Ceram. Abs.*, **18** [7] 195 (1939). G.R.S.

Determining the elasticity modulus of ceramic industrial materials. OTTO KRAUSE AND HSUN-SHAN-CHEN. *Sprechsaal*, **72** [22] 283–86 (1939).—For systematic study of the dependence of the elasticity modulus of ceramic industrial materials on the composition of the mix, the firing treatment, and other influences, the measurement of the deflection of small test pieces has a considerable advantage. Tests on hard porcelain showed that small cylindrical test rods sag in proportion to the load and can be made apparently free from tensions. The elasticity moduli of different fine ceramic materials measured by this process are given. The values vary less than ±5%; the accuracy of measurement attained is satisfactory for serial examination. M.V.C.

Drying ceramic products using induced ultra-high frequency electrical energy. T. C. VAUGHAN, H. E. RIVERCOMB, W. A. MURRAY, AND J. W. WHITTEMORE. *Jour. Amer. Ceram. Soc.*, **22** [9] 281–85 (1939).

Drying with near-infrared radiation. L. S. ICKIS AND HOWARD HAYNES. *Gen. Elec. Rev.*, **42** [4] 145–49 (1939).—A series of drying tunnels is described in which the radiant heat is supplied by 250-w. drying lamps. Such application is most effective for vaporizing the most common solvents and washes. In porcelain enamel surfacing, where the material is applied in a water solution, the drying lamps very satisfactorily remove the water films. This near-infrared drying is simple. Heat control is positive and flexible, and the tunnels require no warming-up period. Illustrated. L.E.T.

Effect of certain impingement dust-sampling instruments on the dust particles. E. L. ANDERSON. *Jour. Ind. Hyg. & Toxicol.*, **21** [2] 39–47 (1939).—The impingement type of dust-sampling apparatus fractures the larger dust particles. The findings of Ficklen and Goolden (*Ceram. Abs.*, **17** [5] 192 (1938)) are verified under more elaborately controlled testing conditions. Dust counts made by an impingement type dust-counter are erroneous as they always give a higher count than actually exists in the air sampled. With any dust, an estimation of particle-size distribution in the air from the particles taken by an impingement type dust-counter is erroneous, erring in the number of fines. E.J.V.

"Electric ear," device for automatically controlling ball mills by their sound. HARLOWE HARDINGE. *Amer. Inst. Mining Met. Engrs. Tech. Pub.*, No. 1076; *Mining Tech.*, **3** [4] 18 pp. (1939).—This device has operated successfully in dry grinding with ball, rod, and tube mills on both open and closed circuit; in wet grinding with ball, rod, and tube mills; and on 12-in. to 10-ft. mills. A 6.5- x 12.5-ft. ball mill in closed circuit with a classifier averaged 1182 tons per day with 14.8% plus 65 mesh on manual control; with the "electric ear" the capacity averaged 1304 tons per day with 15.0% plus 65 mesh. See "Exhibit—," *Ceram. Abs.*, **17** [4] 150 (1938). W.D.F.

Filtration and the Four-Year Plan in the ceramic industry. HANS RUDOLPH. *Ber. Deut. Keram. Ges.*, **20** [4] 200–10 (1939).—R. reports that a satisfactory substitute for cotton filter cloths is a synthetic thermoplastic known as Flexolith. The filtration rate is 2 to 3 times greater, the degree of dewatering is not relative to filtration rate and is 5 to 10% greater, repair and washing are eliminated, filter life is almost without limit (a test showed over 500 presses with the new medium without change, corresponding to 6 cotton cloth changes for the same service), and the material lends itself to improved design of filter apparatus. C.H.R.

Hard-facing mining machine bits. JOHN PARKER. *Mining Congress Jour.*, **22** [11] 48–49 (1936).—The Wheelwright, Ky., coal mine of the Inland Steel Co. uses Borod to retip their bits. W.D.F.

High-temperature lubrication. B. H. PORTER. *Ind. Heating*, **6** [7] 602–604 (1939).—A stable homogeneous suspension of colloidal graphite in petroleum oil is used as lubricant for minimizing friction and resisting oxidation in furnace and kiln-car bearings, conveyers, glass machinery, and other parts operating under high temperatures. The method of colloidizing graphite is briefly described. Owing to its extremely fine size, colloidal graphite penetrates to all parts requiring lubrication without being destroyed by the high temperatures. A mixture of 2% by weight of colloidal graphite in 98% of fluid carrier gives a suitable lubricant. See "Lubrication—," *Ceram. Abs.*, **18** [9] 249 (1939). M.H.

Instrument firing. E. T. W. BAILEY. *Steel*, **103** [23] 54–55, 73–74 (1938).—B. describes in detail a modern installation of automatic open-hearth control and its operation. The characteristics of each instrument are pointed out and the actual results are listed. H.E.S.

Interferometer as an aid in ceramic research: II. H. LEHMANN AND M.-T. SCHULZE. *Zeiss Nachr.*, **2** [8] 267–74 (1938).—Expansion measurements on bodies and glazes were carried out with the aid of the interferometer. Test pieces thinner than 0.4 in. in diameter were used. To be accurate and final, measurements require the use of glazes fused to the body under regular manufacturing conditions. A photo of a semivitreous body is given which shows the body itself, the glaze, and the intermediate layer. The measurements are given in a table; the values are considerably affected by number and temperature of the heats. Data are also given for the coefficient of expansion of $PbO \cdot SiO_2$ from 20°C to 320°C. For Part I see *Ceram. Abs.*, **16** [3] 94 (1937). L.E.T.

Machinery for the preparation of clay in the ceramic industry. O. REUMANN. *Tonind.-Ztg.*, **63** [13] 140–43; [14] 152–54; [17] 186–90; [24] 277–78; [32] 374–76 (1939).—R. gives a short general description of the apparatus used for the mixing, grinding, screening, and drying of raw materials used in the ceramic industry. No details or dimensions are given. Illustrated. W.K.

Measurement of evaporation. K. SPINGLER. *Tonind.-Ztg.*, **62** [29] 329–30 (1938).—S. describes two simple devices for measuring the rate of evaporation. Piche's apparatus consists of a calibrated test tube and a piece of plotting paper while Livingston's consists of a weighed sphere of plaster of Paris. W.K.

Measurement of temperature of molten steel by means of a tungsten-carbon thermocouple: II. K. SASAGAWA AND T. OMURO. *Tetsu-to-Hagane*, **25** [1] 1–8 (1939).—A pyrometer which measures molten steel accurately and easily has been constructed. This new tungsten-carbon thermocouple is constructed as follows: Tungsten wire, one end of which is flat, is inserted in a carbon tube; this flat end is in contact with one end of the tube, a spring holding the contact. The end makes a hot junction, and it is covered with a carbon cap instead of an ordinary refractory cover, as the time lag of heat conduction is very small. This carbon cap is dipped directly into molten steel. The part which is in contact with the molten slag has double protection, the carbon tube and a refractory tube. With this method, it is unnecessary to use inert gases (H_2 or N_2) to prevent oxidation of the couple. The temperatures of molten steels in the open-hearth, electric, and high-frequency electric furnace are given, and steel melting is discussed. Y.K.

Mechanical properties and corrosion resistance of nickel at elevated temperatures. E. R. THEWS. *Chem. App.*, **26** [10] 158–59; [11] 174–76 (1939).—T. reviews the properties of Ni which make it a useful material in apparatus and machinery for use at temperatures up to 500°C and higher. In general, 500° is about the limit for continuous use in practice if the permissible wear is rather limited. M.H.

Method of recording the plastic properties of porcelain bodies. L. E. THIESS. *Jour. Amer. Ceram. Soc.*, **22** [9] 286–89 (1939).

Methods of re-pressing refractory brick. G. W. *Tonind.-Ztg.*, **62** [31–32] 349–50 (1938).—W. discusses methods used and precautions to be taken in re-pressing refractory brick and shapes. W.K.

Microapparatus for temperature-time curves and a high-temperature thermostat. W. E. L. BROWN. *Jour. Sci. Instruments*, **16** [6] 195–99 (1939).—B. describes a thermopile with which "difference" curves can be taken, using alloy specimens weighing about 0.1 g. sealed in silica tubes. The thermopile is used in a high-temperature thermostat

furnace whose windings form a resistance thermometer and a Wheatstone bridge. The furnace can be used to maintain a constant temperature or to give a steady rate of temperature change over a limited range. Two figures. J.L.G.

Modern rust-preventing paints. F. OHL. *Oberflächentech.*, **16** [13] 131–33 (1939).—Among the recent developments in rust protection is Silear (a pure silicon carbide), a quartzlike material. A 1 kg. mixture of 60% Silear and 40% lead oxide covers 10 m.² while 40% lead oxide with 60% barite covers only 6.5 m.². The material is not poisonous. Leadwhite Z is a mixture of pure lead white and 30% Zn white; the admixture of Zn white contributes to the hardening of the coating. Zinc oxide is used, as its high saponification power prevents the destruction of the binder; it also gives a smooth bright surface. The various forms of bronzes, i.e., metal powders, are discussed. Al-Si alloy powders show an excellent corrosion resistance. Graphite is the best pigment, as neither physical nor chemical substances change or destroy it, and it does not enter into reaction with the base metal. M.H.

Photoelastic method of stress analysis. R. D. MINDLIN. *Jour. Applied Physics*, **10**, 222–41 (1939).—M. reviews in detail the fundamental principles upon which the photoelastic method is based and the improvements in techniques and the widening fields of application during the ten years since the publication of Coker and Filon's Treatise on Photoelasticity. 181 references. A.P.

Precise measurement of drying shrinkage. F. H. NORTON. *Ceram. Age*, **33** [1] 7–8 (1939).—N. gives details of construction and operation for an apparatus which makes a precise measurement and correlation of the drying shrinkage and loss of weight of cylindrical clay test specimens. Illustrated. F.G.H.

Psychrometric chart; its application and theory. WILLIAM GOODMAN. *Heating, Piping & Air Conditioning*, **11** [6] 357–60 (1939).—The psychrometric chart is used for elementary purposes, e.g., to show the relationship between dry-bulb, wet-bulb, and dew-point temperatures and relative humidity. In addition it provides a simple means of analyzing many complex problems in comfort and process air conditioning. New psychrometric charts covering low-, middle-, and high-temperature ranges with saturation curves for various barometric pressures are presented. The theory of the psychrometric chart is discussed in detail, and methods of solving problems by the use of charts are described. J.L.G.

Remote temperatures. LEEDS & NORTHRUP CO. *Steel*, **103** [12] 63, 141–42 (1938).—These devices indicate temperatures without contacting or being adjacent to the work and are in general of two types. In one type the energy from a hot body passes through an opening in a tube end and is focused upon a thermopile element at the far end of the tube by means of a mirror. This type is suitable for such applications as measuring furnace temperatures. The second type utilizes a lens to focus radiation from a hot body upon a thermopile at the far end of the instrument. These afford temperature indications over very small areas such as individual pieces of a line of moving parts in a continuously operated furnace. This principle eliminates temperature differential between furnace and work from the control system, thus increasing the accuracy considerably. See "Furnace—," *Ceram. Abs.*, **18** [1] 28 (1939). H.E.S.

Respirator for use in dust-laden atmospheres. Mark IV dust respirator. J. A. SADD, H. L. GREEN, G. DAVIES, V. S. NICHOLSON, A. S. G. HILL, and H. H. WATSON. *Chem. & Ind.*, **57** [34] 781–91 (1938).—The respirator consists of a molded rubber facepiece carrying two filter units, an outlet valve, and harness. Data are given on the characteristics of various dusts in industry, samples of which were taken by means of the thermal precipitator. The choice of filtering materials and the theory of filtration are discussed. Methods of making tests and the results obtained are given. A filtering material composed of a Merino wool-asbestos mixture had filtering characteristics superior to any found in existing dust respirators or in any of the materials investigated. G.R.S.

Shattering of dust particles by the impinger. D. G. BEADLE. *Jour. Ind. Hyg. & Toxicol.*, **21** [4] 109–20 (1939).—Experiments were carried out to determine whether certain instruments which collect dust by impingement shatter the dust particles during the impingement. Previous work and certain theoretical considerations indicated that this was likely to occur. The Owens dust-counter and the konimeter were studied. Dust clouds of various size distributions were sampled, using the two impingers and also thermal precipitators; the latter instruments are highly accurate for dusts of the type used. For dusts containing small percentages of the finest particles, the impingers showed more very fine particles than the thermal precipitators. This result and other conclusions given leave little doubt that both these impingers shatter some of the coarse particles, giving rise to numbers of fine particles which are not actually present in the dust clouds. Experiments were carried out with the konimeter slide treated in special ways. Some samples were taken underground. The underground samples confirmed the laboratory experiments. E.J.V.

Shattering of dust particles in the impinger. H. H. WATSON. *Jour. Ind. Hyg. & Toxicol.*, **21** [4] 121–23 (1939).—The number of particles per unit volume of air as computed from the dark-field impinger count may be too high, due to the shattering of discrete particles and the breaking up of aggregates by impact on the impinger plate or flask. E.J.V.

Small electric arc furnace for melting and pouring glasses and corrosive slags. J. A. TAYLOR. *Bull. Amer. Ceram. Soc.*, **18** [8] 297 (1939).

Survey of crystal optics. JOSEPH VALASEK. *Jour. Applied Physics*, **10**, 209–21 (1939).—V. discusses the theory, equipment, and technique of crystal optics, especially in regard to its application to photoelasticity. A.P.

Teeming temperatures. E. H. WALDMAN. *Steel*, **103** [21] 44–45 (1938).—W. recommends the use of the optical pyrometer as a control instrument to aid in improving open-hearth practice and gives details of the procedure involved. H.E.S.

Thermal conductivity of insulating materials and methods of testing. EZER GRIFFITHS. *Jour. Inst. Heating & Ventilating Eng.*, **5** [49] 21–36 (1937).—Difficulties in thermal-conductivity measurements are due to the time required to attain equilibrium temperature and to heat leakage. A guard plate or guard ring is used to eliminate distortion of the heat-flow lines through the section of the test sample under study. G. describes two types of apparatus, one for specimens 12 x 12 in. and 1 to 2 in. thick and the other for specimens 36 x 36 in. and 3 to 12 in. thick. Results are given for light concretes and multiple partition forms of insulation. See *Ceram. Abs.*, **17** [2] 74; [8] 293 (1938). J.M.N.

Welding as aid to the pottery and glass industry. C. W. BRETT. *Pottery & Glass Record*, **21** [7] 183–84 (1939).—Welding is often cheaper than replacement by a new part and is better than a mechanical repair. Steel can now be welded quite satisfactorily and then given a superfine finish, and the results can be guaranteed. It is no longer necessary to preheat cast iron and malleable iron before welding, and nonferrous alloys can be welded satisfactorily. Welding is unequalled as a means of reducing maintenance costs. A.B.S.

SEPARATE PUBLICATION

Testing Fans (Excluding Mine, Ceiling, and Desk Fans). British Standard Specification No. 848—1939. BRITISH STANDARDS INST., London, May, 1939. Price 2s.—Various types of fans and the terms relating to fan performance are defined. 18 illustrations. A.B.S.

PATENTS

Apparatus for classifying finely granulated solids according to size. H. E. T. HAULTAIN. U. S. 2,168,207, Aug. 1, 1939 (May 21, 1936).

Apparatus for cooling cement clinker, etc. J. S. FASTING. Brit. 508,500, July 12, 1939 (Dec. 31, 1937).

Apparatus for manufacturing pottery ware. W. J. MILLER. Brit. 508,154, July 12, 1939 (July 15, 1938).

Extreme-pressure lubricant. A. W. RALSTON (Armour & Co.). U. S. 2,168,848, Aug. 8, 1939 (July 29, 1936).—A lubricant especially adapted for extreme pressure lubrication comprises a lubricant and an alkylthioamide having at least 6 carbon atoms in the alkyl radical.

Grinding mills of the edge-runner type. H. J. & A. COULTHURST, LTD., AND H. COULTHURST. Brit. 508,877, July 19, 1939 (Feb. 2, 1938).

High-temperature pyrometer. L. R. RUNALDUE (General Electric Co.). U. S. 2,166,824, July 18, 1939 (Jan. 14, 1936).—A high-temperature pyrometer comprises a device responsive to radiant energy, means for segregating two separate wave lengths of received energy from the total wave lengths thereof and for applying them separately to the device, and means responsive to the device for varying the relative amounts of energy of the segregated wave lengths applied to the device, whereby the device makes the same response when subjected to either of the segregated wave lengths.

Hydraulic press with variable retraction for platens. P. C. POCOCK AND V. S. SHAW (Hydraulic Press Corp., Inc.). U. S. 2,166,319, July 18, 1939 (Dec. 8, 1937).

Jolleying of pottery, etc. E. S. SHERMAN. Brit. 508,321, July 12, 1939 (Jan. 21, 1938).

Method and system for testing high-voltage insulation. GEORG KEINATH (Siemens & Halske, A.-G.). U. S. 2,166,932, July 25, 1939 (March 16, 1936).

Microphotographic apparatus. J. H. O'NEILL. U. S. 2,166,419, July 18, 1939 (Dec. 18, 1937).

Mineral-classifier machines. C. W. LIVINGSTON. Brit. 508,339, July 12, 1939 (July 26, 1938).

Kilns, Furnaces, Fuels, and Combustion

Combustion of coal layers: I. KH. I. KOLODTSEV. *Zhur. Tekh. Fiz.*, **9** [4] 305–14 (1939).—A 15-cm. layer of coal was burned in a combustion chamber with air being forced downward through the layer at rates of 0.01 to 2.0 m./sec. The products of gasification passed downward through the coal bed and were cooled and analyzed. Results show that hydrodynamic conditions are the chief factors controlling the combustion of coal layers. With an air flow of 1 m./sec. and in the absence of secondary reactions the outflow of primary products of combustion is complete. Absolute values of CO/CO_2 depend upon the types of coals. B.Z.K.

Direct firing of rotary kilns with air pulverizers. Cz. *Tonind.-Ztg.*, **61** [53] 587–89 (1937).—C. discusses the objections to the introduction in German industry of the unit system of burning pulverized coal in rotary kilns. The main difficulty is the interruption of production in case of a breakdown of the pulverizer. W.K.

Electric kilns for the glass and ceramic industry. WILHELM WEBER. *Elektrotech. Z.*, **60** [10] 289–91 (1939).—Several types of periodic and continuous electric kilns are described. For painted glass, small periodic furnaces of 0.25 to 1-cu. m. capacity are used; for a larger production of decorated glass, kilns with a capacity of 3.5 cu. m. are required. Such kilns are brought up to temperature in 4 hr. and cooled in approximately 7 hr. An illustration is given of an electric tunnel kiln for firing decorated porcelain ware (850° to 950°C) with a capacity of 2500 kg. porcelain in 24 hr. The power consumption is 0.25 kw.-hr./1 kg. of ware. 3 illustrations. L.E.T.

Electric tunnel kilns in modern ceramic industry. A. RITTGEN. *Sprechsaal*, **72** [17] 209–12 (1939).—The two types of electric tunnel kilns, the chamber kiln and the continuous tunnel kiln, are differentiated according to the method of charging, e.g., the chamber kiln is charged intermittently while the tunnel kiln operates continuously and thus saves 50 to 70% more energy, according to its construction. The arrangement of the ceramic plant, the position, construction, and operation of the tunnel kiln, and its future development are discussed. M.V.C.

Future development of tunnel kilns in the fine ceramic industry. F. DETTMER. *Ber. Deut. Keram. Ges.*, **20** [5] 227–45 (1939).—Recent and future gas and electric tunnel kiln development is discussed in detail. The gas-fired kiln no longer is inferior to the electric kiln in ease of control and certainty of operation but leads in universal application and in maximum temperature development. Much is being done to improve the labor efficiency in kiln operation. C.H.R.

Measuring temperatures in tunnel kilns by creeping thermocouples. N. A. SOKOLOV. *Zavodskaya Lab.*, **7**, 801–804 (1938).—Creeping thermocouples were substituted for stationary thermocouples for temperature control in a 74-m. tunnel oven for annealing malleable cast iron. This permitted the determination of temperature difference between the top and bottom of the oven and between its sides and the temperature of the useful space inside the melting pots over the whole length of the oven. The thermocouples were four chromel-alumel thermocouples each 2 m. long, a constantan wire 100 m. long, and five copper wires each 100 m. long, one of which was welded to the constantan wire. P.B. & E.S.

Reconstruction of a periodic kiln to a continuous kiln. A. N. KHOKHEL. *Keramika*, **1939**, No. 1, pp. 25–27. P.B. & E.S.

Small furnace decorates 500 dozen per day. ANON. *Ceram. Ind.*, **28** [2] 148–50 (1937).—A decorating furnace for firing overglaze decorations, installed at the Red Wing (Minn.) Potteries, Inc., is operated at 1300°F but has been fired up to 2020°F without trouble. Silicon carbide slabs are used to carry the ware through the kiln. Other features of this plant are described. E.J.V.

Technique of burning fuel oil and natural gas. F. G. PHILO. *Mech. Eng.*, **60** [4] 315–20 (1938).—Illustrated. F.G.H.

BOOKS AND SEPARATE PUBLICATION

Applied Thermodynamics. V. M. FAIRES. Macmillan Co., New York, 1938. 374 pp. Price $3.90. Reviewed in *Mech. Eng.*, **60** [10] 782 (1938). F.G.H.

Elements of Thermodynamics. E. M. FERNALD. McGraw-Hill Book Co., New York, 1938. 2d ed. 330 pp. Price $3.50. Reviewed in *Mech. Eng.*, **60** [9] 712 (1938). F.G.H.

Fuel-Fired Furnaces. British Standard Test Code No. 859—1939. BRITISH STANDARDS INST., London. Price 3s 6d net.—This report for use in the evaluation of furnaces, ovens, kilns, boilers, and carbonization plant furnaces consists of two forms, one for quickly testing industrial furnaces and the other for the complete evaluation of a furnace or plant. The data are arranged in 184 items, and there are 180 notes to guide the user of the forms. A.B.S.

Heat and Thermodynamics. M. W. ZEMANSKY. McGraw-Hill Book Co., New York, 1937. 388 pp. Price $4.00. Reviewed in *Mech. Eng.*, **60** [2] 174 (1938). F.G.H.

Oil Heating Handbook. H. A. KUNITZ. J. B. Lippincott Co., Philadelphia, 1937. 2d ed., revised. 464 pp. Price $3.50. Reviewed in *Mech. Eng.*, **60** [4] 347 (1938). F.G.H.

Practical Heat. Edited by T. CROFT, revised by R. B. Purdy. McGraw-Hill Book Co., New York, 1939. 2d ed. 726 pp. Price $5.00. Reviewed in *Mech. Eng.*, **61** [7] 557 (1939).—This book provides a textbook on heat which can be used by those with no mathematical equipment other than arithmetic. F.G.H.

Problems on Applied Thermodynamics. V. M. FAIRES AND A. V. BREWER. Macmillan Co., New York, 1938. 137 pp. Price $1.40. Reviewed in *Mech. Eng.*, **60** [10] 783 (1938). F.G.H.

Science of Petroleum. Edited by A. E. DUNSTAN, A. W. NASH, B. T. BROOKS, AND H. TIZARD. Oxford University Press, New York, 1938. 4 vols. 3192 pp. Price $85.00. Reviewed in *Mech. Eng.*, **60** [5] 433 (1938). —This work, which is intended as an encyclopedia of the petroleum industry, contains a balanced comprehensive critical discussion of every aspect of the prospecting, production, refining, and transport of mineral oil and gas. Over three hundred specialists have contributed to it. The first volume is devoted to the origin and production of crude petroleum. Volumes 2 and 3 discuss the physical and chemical properties of petroleum. Volume 4 deals with the utilization of mineral oils and their derivatives, detonation and combustion, and bituminous materials and their products. The work is illustrated by maps, charts, and photographs; bibliographies are appended to the sections, and name and subject indexes are provided. The treatise should be most valuable to all workers in this field. F.G.H.

Steam and Gas Engineering. T. E. BUTTERFIELD, B. H. JENNINGS, AND A. W. LUCE. D. Van Nostrand Co., New York, 1938. 3d ed. 490 pp. Price $4.50. Reviewed in *Mech. Eng.*, **61** [1] 81 (1939).—Combustion, fuels, and fuel-burning equipment are discussed in detail. F.G.H.

PATENTS

Coal- and lignite-gas purification. GEORGES JOSEPH LEONET. Can. 382,679, July 18, 1939 (Aug. 19, 1937). G.M.H.

Electrically heated double tunnel furnaces. W. W. TRIGGS (Akt.-Ges. Brown, Boveri & Cie.). Brit. 508,738, July 19, 1939 (May 9, 1938).

Furnaces for heating kilns, etc. J. WHITELEY AND G. WHITELEY. Brit. 498,338, Jan. 18, 1939 (Sept. 6, 1937).

Gas-fired furnaces. F. C. SIEMENS. Brit. 498,217, Jan. 18, 1939 (Nov. 15, 1937).

Geology

Agalmatolite occurrences in Minas Geraes, Brazil. L. J. D. MORAES AND V. LEINZ. *Chem. Erde*, **12**, 95–103 (1938).—Deposits of pyrophyllite suitable for ceramic use in the province of Minas Geraes are described. It is concluded that the pyrophyllite deposits have been formed from kyanite-rich schists by the agency of pneumatolytic-hydrothermal emanations from the associated granitic bodies. H.I.

Attapulgite. J. DE LAPPARENT. *Bull. Soc. Franç. Mineral.*, **61**, 254–83 (1938).—Arguments for attapulgite as a species of clay mineral distinct from montmorillonite and palygorskite are reviewed. See *Ceram. Abs.*, **17** [8] 288 (1938). H.I.

Bentonite, its use in plastic mixes. PAUL E. COX. *Ceram. Ind.*, **28** [6] 524–26 (1937).—A decidedly plastic natural clay can be rendered nonplastic by the addition of bentonites, and nonplastic natural clays can be rendered plastic by the addition of the proper amounts of bentonite. Bentonite may be used as a base for stoneware glazes. E.J.V.

Brookite in the Millstone Grit of Yorkshire. J. A. BUTTERFIELD. *Geol. Mag.*, **76**, 220–28 (May, 1939).—There are about seven types, including (1) yellow tabular crystals with dumbbell-shaped inclusions of opaque dust, probably iron oxide; (2) a lattice with flat striated prisms arranged at 60° and 120° angles to each other; (3) a fringe formed around leucoxene; (4) a bundle of long, slender, parallel crystals; (5) a cluster of small, stumpy prisms; (6) isolated crystals with a strip of discoloration down the middle and with similar shorter ribs sometimes crossing it; and (7) clear crystals in basal plates. W.D.F.

Cerium and its compounds. A. ESME. *Argile*, No. 195, pp. 5–11 (1939).—In ceramics and glassmaking, metallurgy, and chemistry, cerium compounds have found new and important applications. Designated as a rare earth because it is less well known, it is relatively common in nature and is found in acid igneous rock (frequently pegmatite), associated with uranium and thorium, and in sedimentary rock, greatly dispersed as silicates (orthite) and phosphates (monazite). Orthite is the most important silicate mineral and is a hydrated silicate of iron, aluminum, and cerium. Orthoide is a mineralogical variety; cerite, $2(Ce,La,Di)O \cdot SiO_2 \cdot 4H_2O$, and allanite, $3(Ce_2,Al_2)O_3 \cdot 4(CaO,FeO) \cdot 6SiO_2 \cdot H_2O$, are other silicates. Monazite is an orthophosphate of cerium, lanthanum, thorium, praseodymium, and neodymium and is the only actively exploited variety. Monazitoide is a variety, and koppite is a natural niobate of calcium, cerium, and sodium; cleveite is a uraniferous spinel containing cerium; many multiple rare earths also contain cerium. Monazite sands are usually pale yellow and are found especially in India and Brazil and also in Ceylon, the U. S., Malay, Africa, Madagascar, Canada, the Urals, and Sweden. Cerium oxide is used as a decolorizer for glass and enamels. A pure oxide of cerium called opaline, the formula of which is given in a pamphlet of the Thann and Mulhouse Chem. Products Factory, has recently been developed for the production of gray nickel or cobalt ground enamels for sheet metal. It has remarkable opacity and is not affected by furnace atmosphere. M.V.C.

Clay minerals and their combination with water in green clay and bodies. GUSTAV KEPPELER AND GERHARD AURICH. *Sprechsaal*, **72** [6] 71–75; [7] 83–86; [8] 93–95; [9] 110–13 (1939).—Kaolin, halloysite, bentonite, and mica were dehydrated by heating, and the solubility in HCl of the dehydrated products obtained was determined. The dehydration lasted an average of 6 days for every degree of temperature. The results of previous experiments on kaolin were confirmed. The length of heating time is a decisive influence in dehydrating. In the length of dehydration time selected here, the temperature at which most of the water of constitution escaped was 410°. The impurities detected in a halloysite were identified as probably hydrargillite. A mineral with allophane also contained hydrargillite. Montmorillonite was detected as an impurity in Kärlicher blue clay. Kaolin mixed with soda and lime was calcined, and its absorption capacity for water and swelling when moistened was studied. The swelling of the sodium batch is caused by the absorption capacity of the sodium aluminum silicate permutite structure. The lime batches showed no swelling with sufficient lime additions because the aluminum silicate formed is for the most part resistant to water. The difference in the swelling capacities of feldspar and lime whiteware is better understood from these experiments. M.V.C.

Clays and fuller's earth: IV, Isobar dehydration and absorption of water of clays. F. SCHWARZ. *Sprechsaal*, **72** [12] 147–48 (1939).—Five clays were selected and their dehydration and absorption of water after heating, their swelling capacity, and Debye diagrams were compared. Results are tabulated. For Parts **I–III** see *Ceram. Abs.*, **18** [6] 163 (1939). M.V.C.

Crystal structure of nacrite, $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ and the polymorphism of the kaolin minerals. S. B. HENDRICKS. *Z. Krist.*, **100**, 509–18 (1939).—The lattice constants of nacrite as determined from X-ray data from single crystals are space group $C_s^4 - Cc$; $6[(OH)_8Al_4Si_4O_{10}]$ in unit of structure; a 8.94, b 5.14, c 43.0 Å with $\beta = 90°20'$. The structure closely approaches rhombohedral symmetry. The polymorphic relations of the kaolin minerals, nacrite, dickite, and kaolinite, depend upon the relation of the disposition of hydroxyl groups in one layer to that of oxygen groups in the next adjacent layer. H.I.

Crystal structure of talc and pyrophyllite. S. B. HENDRICKS. *Z. Krist.*, **99**, 264–75 (1938).—The lattice dimensions of talc and pyrophyllite as determined by X-ray data on single crystals are the same as those given by

Gruner (*Ceram. Abs.*, **14** [2] 50 (1935)). The structures of both are fixed in the *a* and *c* directions but individual layers of $[(OH)_2Mg_3Si_4O_{10}]_n$ in talc and of $[(OH)_2Al_2Si_4O_{10}]_n$ in pyrophyllite are randomly shifted by some multiples of *b*/6 along the *b* axis. Most neighboring layers probably have the same relation as two layers in the space group $C_i^1 - Cc$. H.I.

Decomposition of leucite. G. KRÜGER. *Chem. Erde*, **12**, 236–64 (1939).—The effect of varying p_H of solvents on the decomposition of leucite was studied with both dialysis and filtration. The decomposition resulted in all cases in an alkali-free residual skeleton, the SiO_2/Al_2O_3 ratio of which was approximately constant for constant condition of p_H, solvent temperature, grain size, etc. The effect of grain size on the SiO_2/Al_2O_3 ratio is due entirely to the effect of the surface exposed on the p_H of the attacking layer of liquid. Increased temperatures increase the rate of decomposition and lower the SiO_2/Al_2O_3 ratio of the residual skeleton. H.I.

Existence of a monoclinic soda feldspar. T. ITO. *Z. Krist.*, **100**, 297–307 (1938).—From X-ray studies, I. concludes that a monoclinic soda feldspar exists which is submicroscopically intergrown with sanidine in moonstones and which should be regarded as a high-temperature form of the soda series of feldspars corresponding to the sanidine of the potash series. The lattice constants are *a* 7.94, *b* 12.90, *c* 7.12 Å with $\beta = 116°$. H.I.

Froth flotation and agglomerate tabling of feldspars. R. G. O'MEARA, J. E. NORMAN, AND WALTER E. HAMMOND. *Bull. Amer. Ceram. Soc.*, **18** [8] 286–92 (1939).

Froth flotation of talc ores from Gouverneur, New York. J. E. NORMAN, R. G. O'MEARA, AND F. X. BAUMERT. *Bull. Amer. Ceram. Soc.*, **18** [8] 292–97 (1939).

Granitization and associated processes. MALCOLM MACGREGOR AND GILBERT WILSON. *Geol. Mag.*, **76**, 193–215 (June, 1939).—A review and discussion of recent literature is given. Granitization has been important in the evolution of many masses of granites and allied rocks in orogenic regions. Two processes are (I) metasomatism under the influence of permeating emanations ahead of the magma and (II) mechanical penetration of the magma. During I, selective exchanges take place between rock and fluid and promote convergence of different rocks to a common end product. Early stages are essentially thermal metamorphism; final stages are igneous. II may follow I without a break, or II may occur with I incomplete or barely started. II is accompanied by reactions tending toward equilibrium between magma and rock, giving an intermediate product. Granites may result from either or both I and II; which one predominates depends on the supply of emanations and local conditions. In the deeper parts fusion takes place, and these magmas rise and granitize the rock first by I and then by II. At the highest levels, due to loss of energy, rising magma forms true intrusions without modifying the rocks intruded. W.D.F.

Identity of hallerite and of lithium muscovite. J. MALLET. *Bull. Soc. Franç. Mineral.*, **61**, 209–11 (1938).—Hallerite is considered to be a lithium muscovite and not a distinct species. H.I.

Industrial magnesium silicate: talc. V. CHARRIN. *Verre & Silicates Ind.*, **10** [13] 147–49 (1939).—In its pure form, talc is a hydrosilicate of magnesia of the formula $3MgO \cdot 4SiO_2 \cdot H_2O$ corresponding to 31.75 magnesia, 63.50 silica, and 4.75% water. Impurities such as iron, lime, and clay are usually present, however, because talc is a "mineral of alteration" which is derived from eruptive or sedimentary magnesia rock. Talc may be white, green, or gray, with a pearly or oily luster. It is flexible, infusible, resistant to acids, and has a hardness of 1. M.V.C.

Kyanite in eastern Alabama. EDGAR BOWLES. *Bull. Amer. Ceram. Soc.*, **18** [8] 316 (1939).

Kyanite-gedrite parageneses. C. E. TILLEY. *Geol. Mag.*, **76**, 326–30 (1939).—Kyanite associated with orthorhombic amphibole, gedrite, is found in the Archaean gneisses of the White Sea area, U.S.S.R. This is one of the first occurrences of this association reported. Important minerals in the rock are gedrite, kyanite, garnet, and quartz; accessory minerals are biotite, apatite, magnetite, and andesine. Chemical analysis of the gedrite shows that in this highly aluminous environment aluminum has partially replaced silicon in the crystal structure. Gedrite usually tends to react with aluminum silicates to form cordierite, etc., but this has not occurred here. W.D.F.

Lateritic decomposition of the granite in the region of Macenta (French Guinea). J. DE LAPPARENT. *Compt. Rend.*, **208** [23] 1767–69 (1939).—The normal composition of the granite in this area is mica 8, calcosodic feldspar (oligoclase-andesine) 43, potassic feldspar (microcline) 13, and quartz 36%. In this normal granite, corroded masses are found in places where the calcosodic feldspar contains numerous flakes of gibbsite, $Al(OH)_3$; other constituents of the granite are not changed. The amount of gibbsite is 14 to 16%. In general, the following three stages of decomposition of the granite can be distinguished: (1) slight change in the deeper strata leading to sericitization of a small mass of the calcosodic feldspar; (2) sandification of the granite; (3) contrasting change of granite rocks and sand; the former remain micaceous and become gibbsitic, while the latter loses its mica, becomes kaolinic, and is entirely free of gibbsite, except in very rare cases. See "Mineralogical—," *Ceram. Abs.*, **18** [1] 34 (1939). M.H.

Lattice limitation of montmorillonite. S. B. HENDRICKS AND C. S. ROSS. *Z. Krist.*, **100**, 251–64 (1938).—Electron and X-ray diffraction patterns were made of thin films deposited from suspension of montmorillonite, magnesium bentonite, and related clay minerals. Individual montmorillonite crystals contain many aluminosilicate layers and these layers have a somewhat regular arrangement with respect to the normal to the layers. H.I.

Light output and secondary emission characteristics of luminescent materials. S. T. MARTIN AND L. B. HEADRICK. *Jour. Applied Physics*, **10**, 116–27 (1939).—Light output, current-density characteristics, and persistence characteristics are given for zinc sulfide, calcium tungstate, willemite, and several other phosphors sprayed on Nonex glass and bombarded by electrons. A.P.

Luminescent materials. H. W. LEVERENZ AND F. SEITZ. *Jour. Applied Physics*, **10**, 479–93 (1939).—An excellent digest of the theory of luminescent solids and the properties of inorganic luminescent materials is presented. A.P.

Magmatic apatite, its chemical composition and physical properties. ALFRED KIND. *Chem. Erde*, **12**, 50–79 (1938).—Apatite crystals separated from a number of igneous rocks of different compositions and origins were chemically analyzed, and optical and other physical properties were measured. The effect of the substitution of various radicals and elements on the physical properties, especially index of refraction, is noted. H.I.

Measurements of reflecting power by means of the microscope. L. CAPDECOMME. *Bull. Soc. Franç. Mineral.*, **61**, 5–111 (1938).—C. considers the possible sources of error in the measurement of reflecting power with normally incident light and shows that determinations of reflecting power with the microscope may be made with a precision as great as that of many other optical properties. The method is practicable for the determination of refractive indices and for the identification of metallic minerals, etc. H.I.

Metakaolin. L. TSCHEISCHWILI, W. BÜSSEM, AND W. WEYL. *Ber. Deut. Keram. Ges.*, **20** [6] 249–76 (1939).—A historical sketch of various studies of the dehydrated product of kaolin is presented. X-ray analyses of Zettlitz kaolin, synthetic kaolin, and pholerite are presented in detail. A bibliography is included. Illustrated. See "Ultramicroscopic—," *Ceram. Abs.*, **18** [8] 222 (1939). C.H.R.

Mica pegmatites of Kodarma. S. K. ROY, N. L. SHARMA, AND G. C. CHATTOPADHYAY. *Geol. Mag.*, **76**, 145–64 (1939). W.D.F.

Mining bentonite with two Diesel draglines. ANON. *Excavating Engr.*, **33**, 385–86 (1939).—At Polkville, Miss.,

there is a bentonite deposit 30 in. thick under a sand and clay overburden 16 ft. thick. A large Diesel dragline with a 3-yd. bucket removes the overburden in benches. A dragline with a $^3/_8$-yd. bucket mines the bentonite, loading it into trucks. A large canvas placed between the dragline and the truck catches and keeps clean any spilled bentonite. Two drainage ditches keep water and dirt away. Trucks with a $1^1/_2$ ton capacity with extra heavy springs average 4.5 tons per load on an 18-mile haul when they dump directly into railroad cars. The bentonite is used in oil refineries. W.D.F.

Nonsulfide flotation. F. B. MICHELL. *Mining Mag.*, **60**, 272–77 (1939).—M. reviews modern developments. Calcite, rock phosphate, apatite, graphite, fluorite, rhodochrosite, coal, sulfur, barite, iron ore, quartz, feldspar, and talc are briefly mentioned. W.D.F.

Obtaining boric acid from Inder borates by the sulfuric acid method. L. E. BERLIN. *Zhur. Khim. Prom.*, **15**, 12–16 (1939).—B. investigated the conditions of decomposition of borates by H_2SO_4, the duration of the process, and other factors. Laboratory results were checked in semiplant conditions, and a flow sheet was worked out. See "Production—," *Ceram. Abs.*, **15** [10] 312 (1936). P.B. & E.S.

Phonolite. M. DE BUCCAR. *Argile*, No. 194, pp. 5–9 (1939).—Phonolite (clinkstone) is a compact sonorous feldspar made up almost entirely of orthose-albite and large amounts of soda and potash; its specific gravity is 2.58, the color is greenish or brownish gray caused by the presence of small quantities of pyroxene, its structure and composition vary, and its fusing point is 1200°. Ten parts of feldspar can be replaced by 7 parts by weight of phonolite and 3.4 parts powdered quartz. Phonolite is used in enamels with excellent results and may also be used in the production of glass. The location of French deposits of phonolite is given. M.V.C.

Physical and chemical relationships in the garnet systems, grossularite–melanite and melanite–titanmelanite, as influenced by iron or titanium. MARIE-THERESE MACKOWSKY. *Chem. Erde*, **12**, 123–57 (1939).—Nine garnets belonging to the groups grossularite-melanite and melanite-titanmelanite were analyzed chemically, and their refractive indices, densities, and lattice dimensions were determined. The values for all the properties measured increased linearly with iron or titanium content. H.I.

Problem of granite formation. DJALMA GUIMARAES. *Chem. Erde*, **12**, 82–94 (1938).—From his study of Brazilian granites, G. concludes that migmatitic granites are formed by a progressive metasomatism through the agency of magmatic emanations resulting in the substitution of microcline, quartz, and muscovite for the original plagioclase and ferromagnesian minerals. The same emanations are responsible for the formation of ore bodies frequently found in the fracture zones surrounding granitic masses. H.I.

Qualitative methods of evaluating siliceous materials for Dinas-stone production. S. V. POTAPENKO. *Soviet Geol.*, **8** [11] 92–102 (1938); *Chem. Abs.*, **33**, 5141 (1939).—The chemical and physical specifications are given. See "Classification—," *Ceram. Abs.*, **18** [8] 212 (1939).

Relation of stellerite and epidesmine to stilbite. ADOLF PABST. *Mineralog. Mag.*, **25** [164] 271–76 (1939). H.I.

Separation and analysis of soil clay fractions. A report of the analysis of soils subcommittee of the chemistry section. E. M. CROWTHER AND R. STEWART. *Agr. Progress*, **16**, 55–60 (1939); *Chem. Abs.*, **33**, 5106 (1939).—A comparison of three methods of dispersing the clay fraction of soils, i.e., (1) H_2O_2 treatment followed by leaching with NaCl and dispersion with 0.002 *N* NaOH, (2) direct dispersion with 0.05% Na_2CO_3 solution, (3) direct dispersion with 1% NH_4OH solution, indicated that the first procedure is the most satisfactory. In general, the clays become less siliceous as the particle size decreases, but the relative increase in sesquioxides may consist of Al_2O_3 and Fe_2O_3 in different proportions in different soils. The coarser clay fraction does not consist entirely of SiO_2 but must be at least partly of silicate nature. The methods of silicate analysis are considered to be satisfactory for soil clays.

Stilpnomelane group of minerals. C. O. HUTTON. *Mineralog. Mag.*, **25** [163] 172–205 (1938).—As a result of the study of the petrography, occurrence, chemical composition, and crystal structure, H. concludes that the stilpnomelane group includes a solid solution series with at least two end members, ferro-stilpnomelane (the ferrous mineral) and stilpnomelane (the ferric mineral), and that the group is distinct from the biotite and the chlorite groups. H.I.

Structure of analcite and pollucite. W. H. TAYLOR. *Z. Krist.*, **99**, 283–90 (1938).—Exception is taken to the structural interpretation by Náray-Szabó (see following abstract). H.I.

Structure of pollucite, $CsAlSi_2O_6 \cdot xH_2O$. S. v. NÁRAY-SZABÓ. *Z. Krist.*, **99**, 277–82 (1938).—Pollucite crystallizes in the tetragonal system (pseudocubic) with the space lattice O_h^1° or D_{4h}^{19} with a = 13.74 Å, Z = 16. The structure consists of a skeleton of Si_4O_{12} rings which are connected by AlO_4 tetrahedra, the Cs ions being found in the largest holes in the structure surrounded by 12 O ions at a distance of 3.50 Å. The similarity to the structure of analcite as deduced by Taylor (*ibid.*, **74**, 1 (1930)), with the exception of the position of the alkali ions, is noted. H.I.

Technique of heavy mineral analysis of sandy sediments. WOLFGANG RICHTER. *Zentr. Mineral. Geol.*, **1939A**, No. 3, pp. 70–79. H.I.

Technique of X-ray investigation of soils. J. C. L. FAVEJEC. *Z. Krist.*, **100**, 421–36 (1939).—Methods of mounting specimens and descriptions of patterns for soil fractions less than 2 μ are given. H.I.

Thermal expansion of crystals in relation to their structure. H. D. MEGAW. *Z. Krist.*, **100**, 58–76 (1938). H.I.

Viscosity studies of dickite suspensions. A. W. HELZ. *Jour. Amer. Ceram. Soc.*, **22** [9] 289–301 (1939).

Volatilization of ceramic materials at high temperatures. A. E. BADGER AND W. C. PITTMAN. *Ceram. Ind.*, **28** [3] 218 (1937).—Data on the volatilization losses of chemically pure powdered materials when heated in air at high temperatures are presented, expressed in loss in weight (in g./sq. cm.) of exposed surface per 24 hr. E.J.V.

Weathering of potash feldspar. C. W. CORRENS AND W. VON ENGELHARDT. *Chem. Erde*, **12**, 1–22 (1938); see *Ceram. Abs.*, **18** [4] 114 (1939). H.I.

X-ray examination of mordenite (ptilolite). C. WAYMOUTH, P. C. THORNELEY, AND W. H. TAYLOR. *Mineralog. Mag.*, **25** [163] 212–16 (1938).—Laue and oscillation photographs indicate that the fibrous zeolite, mordenite, possesses orthorhombic symmetry. The unit cell with edges a 18.25, b 20.35, c 7.50 Å contains 4 molecules of the composition $(Ca,Na_2,K_2)Al_2Si_{10}O_{24} \cdot 7H_2O$. The space group is either D_{2h}^{17} or C_{2v}^{12}. The structure is probably based on a framework of linked tetrahedra. H.I.

X-ray examination of some potash-soda feldspars. S. H. CHAO, D. L. SMARE, AND W. H. TAYLOR. *Mineralog. Mag.*, **25** [165] 338–50 (1939).—A series of microperthitic potash-soda feldspars of varying composition was examined by X-rays both in the normal state and after homogenization by prolonged heating at high temperatures. In the untreated microperthite the crystal contains two closely related structures, one (containing the potash feldspar) being monoclinic, and the other (containing most of the soda feldspar) triclinic but different from ordinary albite. In the homogenized specimens only a single structure is present. The cell dimensions of both treated and untreated specimens depend upon the amount of soda feldspar present. H.I.

Zircon, ilmenite, and monazite mining in India. GORDON H. CHAMBERS. *Foote-Prints*, **12** [1] 1–11 (1939).—C. describes the deposits of zircon, ilmenite, monazite, rutile, and garnet found in the beach sands along the Arabian Sea in Travancore. See "Mineral—," *Ceram. Abs.*, **18** [8] 222 (1939). A.P.

Zoned olivines and their petrogenetic significance. S. I. TOMKEIEFF. *Mineralog. Mag.*, **25** [164] 229–49 (1939).—The occurrence of zoned olivines is widespread in igneous rocks. The composition varies from a magnesium-rich center to an iron-rich margin. There is a close relationship between the change in composition of the olivines during crystallization and the change in composition of the magma from which they separate. H.I.

BOOKS

Proceedings of the Sixth Summer Conference on Spectroscopy and its Application. Edited by GEORGE R. HARRISON. The Technology Press; John Wiley & Sons, Inc., New York, 1939. 172 pp. Price $3.00. Reviewed in *Jour. Amer. Chem. Soc.*, **61** [7] 1933–34 (1939).—The identification of minerals is described. See "Spectroscopy—," *Ceram. Abs.*, **18** [7] 192 (1939). F.G.H.

Textbook on Crystal Physics. W. A. WOOSTER. Macmillan, New York, 1938. 108 figs., 295 + xxii pp. Price $4.00. Reviewed in *Jour. Applied Physics*, **10**, 269 (1939). A.P.

PATENTS

Method and means for increasing the strength of bentonitic clay gels. W. B. HIRSCHMANN (American Colloid Co.). U. S. 2,167,455, July 25, 1939 (Nov. 18, 1936).—High-gelling bentonitic clay comprises a mixture of bentonitic clay having incorporated therewith, in a substantially dry state, a high-alumina cement containing monocalcium aluminate as a principal ingredient and having a slower rate of reaction or solution in water than the rate of dispersion of the bentonitic clay in water of the same temperature.

Process of concentrating ores. A. W. RALSTON AND W. O. POOL (Armour & Co.). U. S. 2,168,849, Aug. 8, 1939 (May 23, 1938).—In the froth flotation process of separating ore values from acid insoluble gangue, a step includes subjecting the ore to froth flotation in the presence of a secondary amine flotation agen chosen from the group consisting of secondary aliphatic amines and water-soluble salts thereof, at least one of the alkyl radicals of such amine or amine salt having from 6 to 18 carbon atoms.

Treatment of beryllium ores. DANIEL GARDNER (Mij. voor Thermo-Chemie N.V.). U. S. 2,166,659, July 18, 1939 (March 7, 1938).—In a process for treating beryllium ore for the production of beryllium therefrom, sulfidizing the ore in the presence of a substantial proportion of carbonaceous material at a temperature ranging from about 1800° to 2000°C, whereby volatilization of the beryllium sulfide is substantially prevented, and for a length of time sufficient to convert the greater part of the beryllium in the ore into beryllium sulfide, treating the reaction mass with an excess of a diluted strong mineral acid, filtering the mass, isolating from the filtrate thus obtained the beryllium compound in the form of oxide, converting the beryllium oxide thus isolated into beryllium sulfide, and reducing the beryllium sulfide thus obtained to beryllium metal.

Chemistry and Physics

Application of the glass electrode to the measurement of the p_H of slightly buffered and unbuffered solutions. E. G. EDWARDS AND D. P. EVANS. *Jour. Chem. Soc.* [London], 1937, p. 1938.—The alkaline drift observed when using the glass electrode in unbuffered solutions has been avoided by agitating the liquid in contact with the membrane. The p_H values obtained when soft glass electrodes were used for solutions of acids and neutral salts agree very well with those given by the isohydric indicator method. The apparatus is also suitable for measuring the p_H of slightly buffered acidic solutions in which the H-ion concentration is slowly changing. R.A.G.

Colorimetric determination of fluorine with ferron. JOSEPH J. FAHEY. *Ind. Eng. Chem., Anal. Ed.*, **11** [7] 362–63 (1939).—The colorimetric determination of fluorine, using the ferron-iron reagent described, is applicable to a wide range of materials, including rocks and minerals having up to 10% of fluorine and natural waters with a minimum fluorine content of 1 p.p.m. F.G.H.

Colorimetric microdetermination of boron. JAMES A. NAFTEL. *Ind. Eng. Chem., Anal. Ed.*, **11** [7] 407–409 (1939).—A microgram procedure for a colorimetric microdetermination of boron involving the reaction between boric acid in the presence of oxalic acid and curcumin is outlined. It is accurate for the extremely low amounts of boron generally found in soil extracts. Illustrated. F.G.H.

Convenient periodic chart of the elements. H. W. LEVERENZ. *Foote-Prints*, 12 [1] 22–24 (1939).—The chart allows a separate vertical line for each element, plots characteristic data for each element to allow quick determination of maxima or minima or of elements having a certain value of the property plotted, gives numerical values for the plotted data, and allows each user to add additional data as wanted. The chart is copyrighted by RCA Mfg. Co., Inc. A.P.

Determination of cadmium in silicate rocks. E. B. SANDELL. *Ind. Eng. Chem., Anal. Ed.*, **11** [7] 364–65 (1939).—Fischer and Leopoldi have shown that cadmium can be determined in the presence of zinc, lead, and certain other metals by shaking a solution containing 5% of sodium hydroxide with a solution of dithizone in carbon tetrachloride; cadmium goes into the carbon tetrachloride as the dithizonate, whereas zinc and lead remain in the aqueous phase. Use can be made of this behavior in the determination of the minute amounts of cadmium occurring in silicate rocks. The first steps of the method are practically the same as those used in the determination of copper, zinc, and lead in rocks (*Ceram. Abs.*, **17** [5] 199 (1938)). The heavy metals of the sample are isolated by shaking the ammoniacal citrate solution of the decomposed rock with a carbon tetrachloride solution of dithizone. The carbon tetrachloride phase is separated and shaken with 0.01 *N* hydrochloric acid. Zinc, lead, and cadmium dithizonates are thus decomposed, and these metals go into the aqueous phase as the chlorides; copper and cobalt remain in the carbon tetrachloride. Cadmium can then be determined in the aqueous phase by Fischer and Leopoldi's method. F.G.H.

Determination of the effective molecular weights of B_2O_3 and SiO_2 in their melts. M. P. VOLAROVICH AND A. A. LEONT'EVA. *Zhur. Fiz. Khim.*, **10**, 439–42 (1937).—Calculation by the Sheppard and Houk formula showed that for SiO_2 at $t = 1380°$, the viscosity of quartz being about 10^{11} poises, about 40 mols of SiO_2 unite to form a complex; at 1250°, $\eta \geqq 10^{13}$ poises. A transition from a high-viscous liquid state to solid quartz glass takes place, about 500 mols uniting together. In the case of B_2O_3, the data characterizing the association of fused B_2O_3 are of the same order as those in the case of SiO_2 but are little affected by temperature. P.B. & E.S.

Elimination of the phosphate radical in qualitative analysis. L. W. N. GODWARD AND A. M. WARD. *Jour. Chem. Soc.* [London], **1937**, p. 1337.—A method is described in which phosphate is eliminated as ammonium phosphomolybdate and calcium is detected as calcium molybdate. R.A.G.

Gas analysis in cement plants. ANON. *Tonind.-Ztg.*, **61** [82] 913–14; [83] 924–26 (1937).—The properties of the absorbing chemicals and the solubility of the gases in the leveling liquid are discussed. Experiences and tests

are reported on the influence of the material of the sampling tube and the velocity and the temperature of the gas. W.K.

Inorganic giant molecules. H. G. GRIMM. *Naturwissenschaften*, **27** [1] 1–11 (1939).—G. presents an elaborate discussion of the atomic structure of various inorganic substances, including silicates. The theory and practical application of such consideration is presented. Illustrated. C.H.R.

Inversion $\alpha \rightleftarrows \beta$ quartz. H. E. v. STEINWEHR. *Z. Krist.*, **99**, 292–313 (1938).—By a suitable optical arrangement, the changes in double refraction and other optical properties parallel to and perpendicular to the optic axis of a single quartz crystal were observed during the $\alpha \rightleftarrows \beta$ inversion. The phenomena observed indicate two intermediate modifications within a range of 4°C near the commonly accepted inversion temperature; the lower modification is apparently biaxial. See *Ceram. Abs.*, **18** [1] 37 (1939). H.I.

Magnesium corner of the three-component system magnesium–silver–thallium. W. KÖSTER AND K. KAM. *Z. Metallkunde*, **31** [3] 84 (1939).—The boundary between the homogeneous and heterogeneous alloys and the eutectic crystallization temperature were determined. Hardness and corrosion resistances were studied. Illustrated. C.H.R.

Methods of dispersion of clay in mechanical analysis. I. E. DUDAVSKIĬ AND M. A. YALYMOVA. *Zhur. Priklad. Khim.*, **11**, 786–800 (1938).—The usual methods of dispersion are unsatisfactory. The dispersion should be carried out in boiling solutions of lithium or sodium salts of weak acids. The amount of the salts should be equal to 4 m.e. to 10 g. of clay. $Na_2C_2O_4$, $Li_2C_2O_4$, Na_2CO_3, Li_2CO_3, Na_2HPO_4, and $Na_4P_2O_7$ are very effective. Sodium oxylate is the cheapest salt. See "Accelerating—," *Ceram. Abs.*, **18** [2] 59 (1939). P.B. & E.S.

Optical properties of very thin layers of potassium. D. HACMAN. *Compt. Rend.*, **208** [25] 1982–84 (1939).—Thin layers of potassium, from monatomic thickness to several monatomic layers, were investigated in regard to their transparency to light from an Hg arc in a quartz lamp. The monatomic layer is perfectly transparent for the visible and invisible radiation except for the spectral region of 3500 to 4000 Å. In this region, the reflection is about 0.35% and the maximum absorption is about 2%. The selective absorption for this range exists also in multiatomic layers and increases with the thickness up to about 6 mμ (12 monatomic layers), in which case it is quite pronounced. M.H.

Partial system Mg–Mg_3Al_2–Mg_3Bi_2 of the three-component system magnesium–aluminum–bismuth. E. SCHEIL AND B. GLAUNER. *Z. Metallkunde*, **31** [3] 76–79 (1939).—The approximate extent of the combining range was determined. The ternary eutectic point occurs nearly on the side of the binary system magnesium–aluminum. The polymorphic conversion of the compound Mg_3Bi_2 does not take part in the reaction. The level Mg_3Al_2–Mg_3Bi_2 is quasi-binary and eutectic in nature. The formation of the α-Mg_3Bi_2 phase is influenced by the crystallization forces of the magnesium solid solution. The bismuth content has no noticeable influence upon the hardness of the cast alloy or on the hardened product. Illustrated. C.H.R.

Partial system Mg–MgZn–Mg_3Bi_2 of the three-component system magnesium–zinc–bismuth. E. SCHEIL AND B. GLAUNER. *Z. Metallkunde*, **31** [3] 80–81 (1939).—The ternary eutectic falls near the binary system, magnesium–zinc, line. The polymorphic conversion of the compound Bi_2Mg_3 does not take part in any other reaction in this partial system. The formation of the α-Bi_2Mg_3 phase is influenced by the crystallization forces of the magnesium solid solution. Bismuth has no noticeable influence on the hardening characteristics of the alloys. Illustrated. C.H.R.

Partial system Mg–$MgZn_2$–Mg_5Tl_2 of the three component system magnesium–zinc–thallium. W. KÖSTER AND K. KAM. *Z. Metallkunde*, **31** [3] 82–84 (1939).—The hardening possibilities of alloys with 10, 20, and 30% Tl were determined for the cast alloys. Additions of thallium decrease the corrosion resistance of magnesium. Increases in zinc and aluminum improve the corrosion resistance of the magnesium-thallium alloys. Illustrated. C.H.R.

Potential of ionic links and its crystallographic importance. WILLI KLEBER. *Neues Jahrb. Mineral. Geol.*, **A75**, 72–89 (1939). H.I.

Preparation of crystalline titanium nitride. V. P. REMIN. *Vestnik Metalloprom.*, **1938**, No. 7, pp. 54–63.—Crystalline titanium nitride was prepared and substituted for diamond by stropping of emery rounds. Pure TiO_2 was fused in an electrical resistance furnace with two carbon electrodes in an atmosphere of nitrogen, nitrogen with hydrogen, and ammonia. The method of preparation, the metallographic analysis, the production process, and the use of crystalline titanium nitride are described. The preparation of crystalline titanium nitride by this method makes possible the use of fused titanium nitride by stropping of emery rounds, but it is necessary to change the principle of operation of the stropping instrument. It is also possible to use the titanium nitride instead of diamond for cutting of glass by light stropping on rapidly rotating rounds. B.E.K.

Quantitative determination of arsenic in organic and inorganic compounds. DAVID T. LEWIS AND VIVIAN E. DAVIES. *Jour. Chem. Soc.* [London], **1939**, p. 284.—Volumetric and gravimetric methods for the determination of arsenic are described. The methods depend on the quantitative precipitation of the arsenic as uranyl ammonium arsenate. In the volumetric process the precipitate is filtered off, and the excess uranium is determined with permanganate. Nitrates or any substances reduced by nascent hydrogen interfere with the volumetric method, and in this case the precipitate is converted into U_3O_8 and weighed as such. Details of a modified Kjeldahl method for the rapid decomposition of organic arsenicals are given, the arsenic then being estimated as above. R.A.G.

Rapid method of determining silica in kaolin clay. KH. I. TSYBULEVSKIĬ. *Zavodskaya Lab.*, **7**, 489–90 (1938).—Finely powdered material in the amount of 0.5 g. is ignited at 700° to 750° for 30 to 40 min. The residue is boiled with 30 to 40 ml. of HCl acid; 30 ml. of H_2SO_4 are added and the solution is evaporated to copious evolution of SO_3. Water (200 to 250 ml.) is added and the precipitate is filtered. The washed residue is analyzed for SiO_2 by the usual procedure. P.B. & E.S.

Rapid method for the qualitative analysis of silicates. AUGOSTO CHAUDET. *Anales Asoc. Quím. Argentina*, **26**, 269–73 (1938); *Chem. Abs.*, **33**, 4906 (1939).—The finely ground silicate is mixed with dry, coarsely ground Mg and placed in a Ni or Fe crucible; the top of the mixture is heated by a flame to start the reaction. The silicate is then decomposable by acid and can be analyzed for everything but Mg.

Space lattice of aluminum boride, AlB_{12}. F. HALLA AND R. WEIL. *Naturwissenschaften*, **27** [6] 96 (1939).—This compound shows $a = 17.01$ Å, $b = 10.98$ Å, $c = 18.80$ Å, $\beta = 110° 54' \pm 6'$; density $\rho = \frac{1^g}{4^{cc}} = 2.569$ and the volume of the elementary cell $V = 3284.4$ Å^3; $n = 446 \sim 448 = 32 \times 14$ atoms in the cell, which is the form AlB_{13} rather than AlB_{12} as previously given by H. Biltz and Wulfing (*Ber. Deut. Chem. Ges.*, **41**, 2634 (1908)). Further work is in progress. C.H.R.

Sulfamic acid in the separation of the rare earths. J. KLEINBERG, W. A. TAEBEL, AND L. F. AUDRIETH. *Ind. Eng. Chem., Anal. Ed.*, **11** [7] 368–69 (1939).—Separation of cerium-free rare earth oxide mixtures into lanthanum and yttrium subgroups is effectively accomplished by conversion to sulfamates and the subsequent treatment of an acidic solution of the sulfamates with sodium nitrite. This method compares favorably with the classical alkali double sulfate procedure. The sulfamates of lanthanum, neodymium, samarium, and yttrium have been prepared. F.G.H.

System iron–zinc: II. F. HALLA, R. WEIL, AND F. GÖTZL. *Z. Metallkunde*, **31** [4] 112–13 (1939).—The monoclinic crystal of the ζ-phase of the iron–zinc system was goniometrically measured. The X-ray structure analysis showed an elementary cell with the following constants: $a = 13.65$ Å, $b = 7.61$ Å, $c = 5.06$ Å, $\beta = 128° 44'$; the space group is C_{2h}^3-$C2/m$. The cell contains two $FeZn_{13}$ mols. Illustrated. C.H.R.

Use and effects of zinc oxide in ceramic products. L. D. FETTEROLF. *Ceram. Ind.*, **28** [5] 424–25 (1937).—Small percentages of zinc oxide are used in semiporcelain, whiteware, sanitary ware, and other similar types of glazes. ZnO in glazes has the following advantages: fluxing power, reduction of expansion and prevention of crazing, contribution to gloss and whiteness, favorable effect on elasticity, increase in maturing range, increased brilliance of colors, and correction of eggshell finish. Zinc oxide is used in dry process cast iron enamel in amounts ranging from 6 to 14%. Its specific functions are to increase fusibility, improve luster, contribute to opacity and whiteness, reduce expansion, and increase extensibility of the enamel film. E.J.V.

BOOKS AND SEPARATE PUBLICATION

Colloidal Phenomena. An Introduction to the Science of Colloids. ERNEST A. HAUSER. McGraw-Hill Book Co., Inc., New York, 1939. 294 pp. Price $3.00. Reviewed in *Jour. Amer. Chem. Soc.*, **61** [7] 1935 (1939). F.G.H.

Comprehensive Treatise of Atomic and Molecular Structure: Vol. 2, Fine Structure of Matter. Bearing of Recent Work on Crystal Structure, Polarization, and Line Spectra: Part I, X-Rays and the Structure of Matter. C. H. DOUGLAS CLARK. Chapman & Hall, Ltd., London. Reviewed in *Science Progress*, **33** [129] 163–64 (1938). C.H.R.

Effects of Errors or Variations in the Arbitrary Constants of Simultaneous Equations. G. H. DELL. *Univ. Illinois Eng. Expt. Sta. Bull.*, No. 309, 50 pp. (1939).—D. studies the effect of variation or errors made in assuming magnitude or quantity of factors occurring in scientific and engineering problems which have to be determined by means of simultaneous equations. The derivation of the theory is given step by step. A sufficiently simple formula is developed which is of practical value in the calculation of the maximum primary error. When the errors in the arbitrary constants are in the neighborhood of 10%, the maximum primary error will probably not differ from the true maximum error by much more than 10%. The apparent maximum error requires a little more time to calculate than the maximum primary error but gives a more satisfactory approximation to the true maximum error over a wide range of conditions. A few practical numerical examples illustrate the application of the theory. M.H.

Second Report on Viscosity and Plasticity. Prepared by the Committee for the Study of Viscosity of the Academy of Sciences at Amsterdam. N. V. Noord-Hollandsche Uitgevers-Mij., Amsterdam; Nordemann Publishing Co., New York, 1938. 282 pp. Price $7.50. Reviewed in *Mech. Eng.*, **61** [7] 557 (1939).—Further developments are discussed. A good summary of current knowledge and theories is given. See *Ceram. Abs.*, **18** [4] 116 (1939). F.G.H.

PATENTS

Beneficiating titanium-bearing siliceous minerals. H. V. ALESSANDRONI (National Lead Co.). U. S. 2,167,627, Aug. 1, 1939 (Oct. 6, 1937).

Making zirconium oxide. C. J. KINZIE AND D. S. HAKE (Titanium Alloy Mfg. Co.). U. S. 2,168,603, Aug. 8, 1939 (Sept. 2, 1936).

Preparation of luminescent materials. BRITISH THOMSON-HOUSTON CO., LTD. Brit. 498,556, Jan. 25, 1939 (Dec. 30, 1936).

Preparation of titanium dioxide pigments. H. V. ALESSANDRONI (National Lead Co.). U. S. 2,167,626 and 2,167,628, Aug. 1, 1939 (Oct. 6, 1937).

General

Action of various mineral dusts on conjunctive tissue studied with the aid of the corneal biomicroscope. A. POLICARD AND J. ROLLET. *Compt. rend. soc. biol.*, **130**, 954–57 (1939); *Chem. Abs.*, **33**, 5087 (1939).—Very small amounts of the finely powdered minerals were introduced into rabbit corneas. Quartz, precious opal, diatomaceous earth, synthetic permutite, and smaltite (Co arsenide) produced a white opaque spot which showed no diminution after five weeks. Sahara sand and fuller's earth produced a less marked reaction. Muscovite and sericite produced a slight reaction which cleared up in four weeks. Low-ash coal dust produced no reaction.

American in France—Story of Theodore Haviland. ANON. *China, Glass & Lamps;* reprinted in *Bull. Amer. Ceram. Soc.*, **18** [8] 312–14 (1939).

Background for ceramics. LAWRENCE E. BARRINGER. *Bull. Amer. Ceram. Soc.*, **18** [8] 275–85 (1939).

Determination of acid insoluble matter in the sputa of silicotics. H. CIVIN, I. A. SCHREIER, G. MARTELLO, AND J. D. HARDY. *Jour. Ind. Hyg. & Toxicol.*, **21** [1] 1–4 (1939).—A method for the determination of acid-insoluble mineral residue in sputum is described. These residues contain 60 to 80% total silica, most of which is quartz. Analyses of 83 nonsilicotic sputa show that the normal range of mineral residue is from 0.2 to 2.5 mg./100 cc. Of the 32 silicotic cases studied, 84% had residues over 2.5 mg.; some had residues as high as 20 mg./100 cc. Many silicotics gave high residues even after years of absence from their dusty occupation. Such determinations may be of value in the diagnosis of silicosis. E.J.V.

Dust-protection devices. E. SMOLCZYK. *Gasmaske*, **8**, 121–29 (1936).—Prewar dust respirators were masks of leather, metal, etc., covering the mouth and nose and having a large dead-air space. Knowledge gained during the war resulted in the respirator Lix, brought out in 1920, which is a light, tight-fitting half mask. It has a filter capsule with replaceable filters and will take felt or sponge filters. It stops the coarser dust particles (larger than 10 microns) almost completely. Improvements and modifications were an exhalation valve; a perspiration drain; facepieces of leather, all rubber, or all metal; and a full mask with goggles or a mask completely covering the head. The harmfulness of dust particles under 10 microns made a better respirator necessary. Improved respirators need a thicker filter or one of greater area. The simplest respirator is the Bilix which has two filter capsules. The best respirator is the "colloid filter"; this has a prefilter to remove coarser material and a chamber attached to the mask which holds the filtering material. Other types have a larger chamber filter carried on the back and attached to the mask by a breathing tube or a tube filter with a filtering material covering a tube kept open by a wire spiral; this tube is worn around the neck. Supplied air respirators give absolute protection and are used in sandblasting. W.D.F.

Effect of grinding on the solubility of mineral substances and on the toxic character of the resulting dusts. MORRIS W. TRAVERS. *Chem. & Ind.*, **58** [10] 226 (1939).—Although silicosis results only from exposure to an atmosphere containing fine dust, it has been assumed that such dust can be produced only by mechanical means and that the effect of mechanical processes involved is only to reduce the material to powder. Long grinding of ore silica sand converts a considerable portion of it into a state in which its heat of solution in hydrofluoric acid is greater than that in the crystalline state, while its density is lower. The solubility of ground silica would therefore be higher than that of crystalline silica. This may account for the poisonous character of mechanically produced dusts. G.R.S.

Equipment and methods for determining air dustiness in mines. CARLETON E. BROWN. *Mining Congress Jour.*, **22** [11] 28–33 (1936).—B. reviews and compares different methods. W.D.F.

Fatal case of uncomplicated silicosis. A. R. RIDDELL, C. M. JEPHCOTT, AND DUDLEY A. IRWIN. *Jour. Ind. Hyg. & Toxicol.*, **20** [9] 566–75 (1938).—A case of silicosis which was characterized by an exposure to a very pure form of quartz dust and by the absence of pulmonary tuberculosis is described. The man operated a sandblast for six years but it was not until the fifth year that symptoms were sufficiently marked to cause him to seek medical advice because of chest pain. This was followed later by dyspnea, cough, expectoration, and other symptoms which necessitated hospitalization 4 months prior to death. During the sanatorium period, the clinical picture presented was that usually associated with an acute respiratory infection. Although the chest roentgenograms indicated silicosis and suggested complicating tuberculosis, at no time were tubercle bacilli demonstrable in the sputum. Initially, the heart rate was rapid and cyanosis was evident. Both these signs became more marked as the case progressed. Pathologically the fibrosis was not excessive and was linear rather than nodular in type. In spite of the radiological appearances there was no evidence of pulmonary tuberculosis. Great numbers of the alveolar spaces were completely filled by an exudate presenting chronic features and were lined by a single layer of mononuclear cells. Probably this produced an interference with the gaseous exchanges in the lungs which occasioned the cyanosis. The chemical and X-ray diffraction analyses of the blasting sand and the siliceous portion of the lung ash indicated that they were composed almost entirely of crystalline quartz. This case emphasizes the necessity of a guarded clinical opinion respecting complicating tuberculosis in the presence of silicosis. E.J.V.

Isolation of the mineral dust in lungs and sputum. N. SUNDIUS AND A. BYGDEN. *Jour. Ind. Hyg. & Toxicol.*, **20** [5] 351–59 (1938).—A method for isolating the dust in pneumoconiotic lungs by the aid of Perhydrol (Merck) containing 30% hydrogen peroxide is described. Through this reagent the organic matter of the lung is decomposed and transferred into solution. The attack on the liberated dust minerals by the organic acids generated during the decomposition is weak, apart from the effect on carbonates which, if present, are mostly dissolved. The characteristic ingredients of asbestotic lungs, the asbestosis bodies, are more resistant, however, and sustain the treatment without visible morphological changes, but the organic matter contained in their gelatinous envelopes is chemically attacked and more or less destroyed. In a sample of sputum rich in iron-ore dust the method was useful for the separation of the mineral content in a practically unchanged state. In cases where the lung dust contains carbonates or where asbestosis bodies are to be isolated without any alteration of their chemical composition, only a purely mechanical method is applicable. For this purpose, a procedure has been practiced which comprises a fine grating of the lung and a subsequent separation of the mineral contents in heavy liquids, among which acetylene tetrabromide diluted with benzene has proved particularly useful. E.J.V.

Nature of mineral particles in sputum and ash of the lungs of silicotics. HUGH E. BURKE AND PAUL F. KERR. *Jour. Ind. Hyg. & Toxicol.*, **20** [9] 535–55 (1938).—It is difficult, with present technique, to identify mineral particles in the residue of the sputum of men who have long been exposed to siliceous dusts. Samples of lung ash of selected portions of the lungs and lymph nodes of four men who were not exposed to siliceous dust in their work and who died with far advanced pulmonary tuberculosis contained large isotropic aggregates of a calcareous phosphatic nature and, occasionally, a few minute doubly refractive particles. Both optical examination and X-ray diffraction analysis of the lung ash of these cases failed to disclose evidence of sericite, feldspar, or quartz. Individual samples of lung ash of 14 or 15 silicotic casualties and a composite sample of lung ash of a group of 8 granite workers contained quartz particles. The lung ash of a granite cutter and the composite sample of lung ash of a group of 8 granite workers carried particles of feldspar as well as particles of quartz. The lung ash of a few of these cases contained small isotropic aggregates. Most of the mineral residue (Jones' method) of portions of the lungs and lymph nodes of a foundry worker consisted of quartz. The residue of the lungs and lymph nodes of a granite cutter contained particles of feldspar as well as particles of quartz. No sericite was found in the ash or mineral residue of any of the proved silicotic cases. The lung ash of one of three men who gave histories of occupational exposure to dangerous, or possibly dangerous, dusts and failed to show silicotic lesions at necropsy carried many minute quartz particles similar to those found in the lung ash of proved silicotic casualties. Doubly refracting particles of undetermined nature were found in the ash in one case. The ash in the third case carried weakly birefringent acicular and fibrous particles, possibly fibrous pyroxenes. E.J.V.

New frontiers for industry. CARL BREER. *Jour. Applied Physics*, **10**, 271–72 (1939).—Progress in any form of human endeavor depends largely on finding new things to do and better ways of doing old things. To achieve these is the essential function of research. No modern industry can survive, function efficiently, or progress without well-organized and intelligently directed research which has the support, guidance, and interest of the management. A.P.

New resistant coatings for hardening the surface of ceramic bodies. W. O. *Emailwaren-Ind.*, **16** [23–24] 154 (1939).—According to a patent of Siemens-Schuckertwerke, A.-G., siliceous ester is coated on the surface of the ceramic body before firing or finishing firing and steam is applied ("Rendering—," *Ceram. Abs.*, **18** [6] 158 (1939)). In an American patent (Siemens & Halske, Berlin) for the soldering of metals to ceramic bodies, powdered iron is dusted on the surface of the body which is then heated to 1220° to 1260° in inert atmosphere until the iron sinters to the surface. The Fe layer can then be hard-soldered. A Swiss patent of Siemens & Halske for joining metallic and ceramic bodies uses silver oxide which is placed between the two bodies and heated to 400° and 700°. The Parker phosphate process (Parker Rust Proof Co., Detroit) and the phosphate coating on iron by the American Chemical Paint Co. are described briefly. A French patent of Skaupy and Weissenberg consists in combining powdered quartz (99.8% SiO_2) with an organic bond, drying at 40° to 50°, and working mechanically. When heated to 800°, the bond is removed and the objects are quickly inserted into the furnace heated to 1500°; the temperature is quickly raised to 1650°. Colors are obtained by adding metal compounds; TiO_2 gives blue. The addition of small quantities of alkali oxides lowers the sintering temperature. M.V.C.

Prevention of silicosis by metallic aluminum. J. J. DENNY, W. D. ROBSON, AND DUDLEY A. IRWIN. *Amer. Doc. Inst. Doc.*, 1174; *Chem. Abs.*, **33**, 3916 (1939).—This appendix describes the determination of SiO_2 by the colorimetric and gravimetric methods, Al determination from the residue of the gravimetric SiO_2 determination, and staining of hydrated Al in tissue sections. A table of buffer solutions used in solubility tests is given, and the preparation of activated amorphous Al, corundum, α-Al monohydroxide, α-Al trihydroxide, and Al powders is described. References are given. See *Ceram. Abs.*, **18** [9] 260 (1939).

Replacing metals by ceramic ware. M. H. KRAEMER. *Ber. Deut. Keram. Ges.*, **20** [6] 277–81 (1939).—K. discusses the rôle played by ceramic ware under the Four-Year Plan in Germany. C.H.R.

Report of Structural Clay Products Research Foundation. D. F. STEVENS. *Bull. Amer. Ceram. Soc.*, **18** [8] 308 (1939).

Solubility of siliceous dusts and the inhibitory action of added dusts. A. G. R. WHITEHOUSE. *Jour. Ind. Hyg. & Toxicol.*, **20** [9] 556–65 (1938).—The solubility of

some silica and silicate dusts in 1% sodium carbonate solution at 37°C was measured. Flint dust was by far the most soluble of the dusts examined, the other dusts in order of solubility being quartz, bull quartz, whinstone, granite, coal-measure sandstone, sericite, and stone dust. The effect of different varieties of stone and coal dust on the solution of silica from quartz dust was studied. The influence of quantity and degree of fineness of the added dust was also determined. The addition of shale dusts, with one exception, reduced the amount of silica dissolved from quartz in 1% sodium carbonate solution. The greatest reduction in solubility of quartz (78%) was caused by gypsum dust, while limestone dusts had little or no effect. Coal dust also inhibited the solution of silica from quartz dust in 1% sodium carbonate solution. The particle size and type of coal dust influenced the reduction in solubility. Values for reduction in amount of silica dissolved varied from 4 to 71%. The solubility of sandstone dust (containing 42% free silica) was reduced when mixed with very fine shale dust. E.J.V.

BOOKS

Industrial Research Laboratories of the United States, Including Consulting Research Laboratories. CALLIE HULL. *Bull. Nat. Research Council*, No. 102, 270 pp. (Dec., 1938). 6th ed. Price $3.00.—An alphabetical list of 1769 manufacturing and commercial companies in the U. S. which maintain research laboratories is presented. Complete indexes of the serial publications, geographical distribution, personnel, and research activities are included. F.J.Z.

Marketing Burned Clay Products, Including an Analysis of Location, Importance, and Development of the Industry. A. HAMILTON CHUTE. College of Commerce and Administration, Bureau of Business Research, Ohio State University, Columbus, Ohio, June, 1939. 374 pp. including index. Price $3.50.—The preface states, "This study of the location and importance of the burned-clay products industries in the United States and of the marketing channels and problems of the manufacturers of these products is addressed chiefly to two groups of readers: (1) manufacturers and distributors of burned-clay products and (2) students of marketing interested in a detailed description of the marketing organization of an industry. The 'commodity approach' employed makes possible a concrete delineation of the actual channels, practices, and problems involved in the marketing of this particular group of commodities.

"For the manufacturers and distributors of burned-clay products, data from a variety of sources are summarized and analyzed so that a bird's-eye view of the industry, including its development, its present importance among American industries, its marketing history, its present policies and practices, and its problems, may be had."

Thirty-six pages are devoted to demand creation and market information for each of the clay-product commodities. Price bases and price policies cover twenty-three pages. Marketing trends and special problems require sixty pages. Altogether, this is one of the most informing books yet published on the history, development, and struggle to meet competition of the burned-clay products industry. It is an archive of the vast amount of NRA data and codes. Covering as it does all clayware, ranging from fine china and utilitarian porcelain to masonry and refractory and abrasive products, this book provides an authentic and complete basis for a study of the past and present development of the clay industries. Although in concise language and replete with condensed data, tables, and charts, this book is very readable. It should be read by the ceramic technologists as well as by the executives and sales staffs of each ceramic manufacturing concern. R. C. PURDY

Notebook for Glass, Ceramics, Enamel, and Cements, 1939 (Agenda pour Verrerie, Céramique, Emaillerie, Cimenterie). Edited by JACQUES WOLF. Ceremver, Bruxelles. 6th ed. Price 30 fr.; reviewed in *Jour. Soc. Glass Tech.*, **23** [96] 122A (1939).—The loose-leaf style of this annual publication is retained in the new edition, the abstracts sections again being supplied monthly. The usual sections, Diary, Technical Tables, and Manufacturers' Advertisements, appear. An index to matter which has appeared in the monthly abstracts issued in 1938 is given.

Smelting Works. Plants for the Winning and Production of Materials (Die Hüttenwerksanlagen. Anlagen zur Gewinnung und Erzeugung der Werkstoffe). H. HOFF AND H. NETZ. Julius Springer, Berlin, 1938. 468 pp. Price 66 Rm. Reviewed in *Mech. Eng.*, **61** [3] 249 (1939).—A comprehensive account is given with considerable detail of the methods and equipment used in metallurgical works and other industrial plants such as glassworks and brickworks where the problem is essentially that of converting raw materials into useful products through large amounts of heat. A great deal of the book is devoted to furnaces and methods of heating. The preparation of fuels and ores, iron smelting and steelmaking, the smelting of nonferrous metals, lime and cement clinkering, ceramic factories, and glassworks are discussed. A bibliography is included, confined almost exclusively to German publications. F.G.H.

Van Nostrand's Scientific Encyclopedia. D. Van Nostrand Co., New York, 1938. 1233 pp. Price $10.00. Reviewed in *Mech. Eng.*, **60** [5] 433 (1938).—This reference book covers the basic sciences of physics, chemistry, mineralogy, geology, botany, astronomy, and mathematics and the applied sciences of engineering, medicine, navigation, and aeronautics. Over ten thousand terms of interest are included, with definitions and fundamental information. The articles are clear and concise, illustrations are used freely, and the information appears to be accurate and up to date. The arrangement is alphabetical with numerous cross references. F.G.H.

PATENTS

Joints between metal parts and ceramic bodies. O. BORMANN. Brit. 508,542, July 12, 1939 (Dec. 29, 1936).

Making artificially colored granules. M. H. VEAZEY (Patent and Licensing Corp.). U. S. 2,168,593, Aug. 8, 1939 (July 31, 1934; Feb. 23, 1938).

STANDING COMMITTEES FOR 1939—1940

Executive Committee, Board of Trustees

A. I. ANDREWS (*ex-officio*): Dept. of Ceramic Engineering, Univ. of Illinois, Urbana, Ill.
C. E. BALES: Ironton Fire Brick Co., Ironton, Ohio
J. L. CARRUTHERS: Dept. of Ceramic Engineering, Ohio State Univ., Columbus, Ohio
E. H. FRITZ: Westinghouse Electric & Mfg. Co., Derry, Pa.
V. V. KELSEY: Dominion Minerals, Inc., 719—15th St., N. W., Washington, D. C.
R. B. SOSMAN: United States Steel Corp., Research Lab., Kearny, N. J.

Finance Committee, Board of Trustees

C. E. BALES, *Chairman*, Ironton Fire Brick Co., Ironton, Ohio
J. L. CARRUTHERS: Dept. of Ceramic Engineering, Ohio State Univ., Columbus, Ohio
C. F. TEFFT: The Claycraft Co., Box 866, Columbus, Ohio
A. S. WATTS: Dept. of Ceramic Engineering, Ohio State Univ., Columbus, Ohio

Committee on Rules

W. KEITH MCAFEE, *Chairman*, Universal Sanitary Mfg. Co., New Castle, Pa. (assisted by members of the Rules Committee of each Division)

Committee on Publications

J. D. SULLIVAN, *Chairman*, Battelle Memorial Institute, Columbus, Ohio
W. W. WINSHIP: Thermal Syndicate, 12 East 46th St., New York, N. Y.
A. N. FINN: National Bureau of Standards, Washington, D. C.
E. E. MARBAKER: Mellon Institute, Pittsburgh, Pa.
R. C. PURDY (*ex-officio*)

Committee on Membership

W. A. WELDON, *Chairman*, 621 Edgewood St., Baltimore, Md. (assisted by members of the Membership Committee of each Division)

Committee on Standards

J. W. WHITTEMORE, *Chairman*, Virginia Polytechnic Inst., Blacksburg, Va. (assisted by members of the Standards Committee of each Division)

Committee on Sections and Divisions

M. E. HOLMES, *Chairman*, N. Y. State College of Ceramics, Alfred, N. Y.
T. S. CURTIS: Industrial Research Lab., Huntington Park, Calif.
REXFORD NEWCOMB, JR.: Industrial Publications, Inc., 59 E. Van Buren St., Chicago, Ill.
E. P. POSTE: 309 McCallie Ave., Chattanooga, Tenn.
L. J. TROSTEL: General Refractories Co., Baltimore, Md.
W. R. MORGAN: Dept. of Ceramics, Rutgers Univ., New Brunswick, N. J.

Committee on Research

ARTHUR A. WELLS, *Chairman*, Homer Laughlin China Co., Newell, W. Va. (assisted by members of the Research Committee of each Division)

Committee on Geological Surveys

H. RIES, *Chairman*, Cornell University, Ithaca, N. Y.
J. E. LAMAR: State Geology Div., Univ. of Illinois, Urbana, Ill.
O. C. RALSTON: U. S. Bureau of Mines, College Park, Md.
W. M. WEIGEL: Missouri Pacific Bldg., St. Louis, Mo.
HEWITT WILSON: Electrotechnical Lab., Bureau of Mines, Norris, Tenn.

Committee on Data

D. G. BENNETT, *Chairman*, Mellon Institute, Pittsburgh, Pa., and F. P. HALL: Onondaga Pottery Co., Syracuse, N. Y. (assisted by members of the Data Committee of each Division)

Special Committee on Data for Geologists' Handbook

LOUIS NAVIAS, *Chairman*, General Electric Co., Schenectady, N. Y.

Committee on Ceramic Education

N. W. TAYLOR, *Chairman*, Dept. of Ceramics, Pennsylvania State College, State College, Pa. (Technology Member, 1 year)
F. H. RHEAD: Homer Laughlin China Co., Newell, W. Va. (Art Member, 2 years)
E. H. FRITZ: Westinghouse Electric & Mfg. Co., Derry, Pa. (Engineering Member, 3 years)
C. M. DODD: Missouri School of Mines and Metallurgy, Rolla, Mo. (Education Member, 4 years)
G. J. EASTER: Carborundum Co., Niagara Falls, N. Y. (Industry Member, 5 years)

Committee on Industrial Management

W. KEITH MCAFEE, *Chairman*, Universal Sanitary Mfg. Co., New Castle, Pa. (assisted by members of the Industrial Management Committee of each Division)

Committee on Patents

F. B. FLICK, *Chairman*, 1706 First National Bank Bldg., Pittsburgh, Pa.
J. C. HOSTETTER: Hartford-Empire Co., Hartford, Conn.
F. H. RIDDLE: Ceramic Div., Champion Spark Plug Co., Detroit, Mich.

Committee on Film Library

H. E. SIMPSON, *Chairman*, Mellon Institute, Pittsburgh, Pa.
C. R. AUSTIN: Battelle Memorial Institute, Columbus, Ohio
R. C. PURDY: 2525 North High St., Columbus, Ohio

Committee on Dust Hazard

F. C. FLINT, *Chairman*, Hazel-Atlas Glass Co., Washington, Pa.
EDWARD SCHRAMM: Onondaga Pottery Co., Syracuse, N. Y.
V. P. AHEARN: National Industrial Sand Association, 951 Munsey Bldg., Washington, D. C.
L. H. MILLIGAN: Norton Company, Worcester, Mass.
L. M. MERRITT: Insulations Inc., Columbus, Ohio

WANTED: ABSTRACTERS FOR THESE JOURNALS

The following journals contain material of interest to readers of *Ceramic Abstracts*. An abstracter for any of these journals should (1) have the journal available in his personal library or in a public, laboratory, or school library to which he has access, (2) be prepared to submit the abstracts regularly each month, and (3) possess a reading knowledge of the language in which the publication is printed. Address all requests for assignments to the office of *Ceramic Abstracts*, 2525 North High St., Columbus, Ohio. Journals will be assigned to those first requesting them.

Abh. Ges. Wiss. Göttingen, Jahresber. Geschäftsjahr, Math.-Physik. Klasse, Fachgruppen
Akad. Vernadskomu Pyatidesyat. nauchn. Deyateln.
Amer. Paint Jour.
Amer. Soil Survey Assn., Rept. Ann. Meeting
Ann. Agron.
Ann. Combustibles Liquides
Ann. Mines
Arbeitsschutz
Arch. minéral. soc. sci. Varsovie
A.S.T.M. Bull.
Australian Food Manuf.
Automobile Engr.
AWF-Mitteilungen
Boll. Soc. Geol. Ital.
Bul. Chim. Soc. Române Chim.
Bul. Labor. Miner. Gener. Univ. Bucuresti
Bull. Acad. Roy. Belgique
Bull. Air Hygiene Foundation
Bull. Amer. Phys. Soc.
Bull. Assn. Tech. Fonderie
Bull. Comm. Géol. Finlande
Bull. Internat. Acad. Yougoslave Sci. Beaux-Arts, Classe Sci. Math. Nat.
Bull. Soc. Ind. Rouen
Bull. Soc. Roy. Belge Ing. Ind.
Chem. Ind. [China]
Chem. Listy
Clay Prod. Jour. Australia
Danish Foreign Office Jour. Com. Rev.
Deut. Goldschmiede-Ztg.
Deut. Tech.
Documentation Sci.
Erde & Stein
Fachausschuss Staubtech., Ver. deut. Ing.
Farbe & Lack
Feinmechanik & Präzision
Gas, Het
Geol. & Bauwesen
Geol. Zhur.
Gesundh.-Ing.
Hutnik
Illustration [Paris]
Ing. Chim.
Ingegnere
Ingeniøren
Iron and Steel of Canada
Izvest. Sektora Fiz.-Khim. Anal., Inst. Obshchei & Neorg. Khim.
Jour. Amer. Soc. Agron.
Jour. Australian Chem. Inst.
Jour. Chem. Eng. China
Jour. Chem. Soc. Japan
Jour. Chinese Chem. Soc.
Jour. Inst. Sanitary Engrs.
Jour. Roy. Soc. W. Australia
Jour. S. African Chem. Inst.
Jour. Soc. Chem. Ind. Victoria
Kalt-Walz-Welt [Supp. to Drahtwelt]
Kinzoku-no-Kenkyu
Koks & Khim.
Kolloid. Zhur.
Legkaya Prom.
Legkie Metally
Machine moderne
Magyar Chem. Folyóirat
Marr State Acad. Bull. [Leningrad]
Mem. Coll. Eng., Kyoto Imp. Univ.
Mem. Phys. Ukrain.
Messtechnik
Metallges. Periodic Rev.
Metallwaren-Ind. & Galvano-Tech.
Mikrochim. Acta
Mineral. Syr'e
Mining Rev. S. Australia
Mitt. Opt. Inst. Tech. Hochschule Berlin
Nachr. Ges. Wiss. Göttingen, Jahresber. Geschäftsjahr Math.-Physik. Klasse
Natuurw. Tijdschrift
Nord. Industriel
Notes & Queries
Österr. Chem.-Ztg.
Periodico mineral. [Rome]
Physica
Physik. Z. Sowjetunion
Platers' Guide
Pochvovedenie
Proc. Acad. Sci. Amsterdam
Proc. Australasian Inst. Mining & Met.
Proc. Geol. Soc. S. Africa
Proc. Illinois Mining Inst.
Proc. Inst. Brit. Foundrymen
Proc. Roy. Inst. Gt. Brit.
Proc. Staffordshire Iron & Steel Inst.
Prom. Org. Khim.
Razvedka Nedr
Redkie Metally
Repts. Min. Ind., Imp. Inst.
Rev. Aluminium
Rev. Chim. Ind. [Rio de Janeiro]
Rev. Géol.
Rev. Ind. Minérale
Schweiz. Tonwaren-Ind.
Sitzber. Akad. Wiss. Wien, Math.-naturw. Klasse
Soviet Geol.
Suomen Kemistilehti
Svetotekhnika
Tech. Blätter
Tech. Gemeindeblatt
Technikai Kurir
Tenn. State Div. Geol. Resources
Trudy Gosudarst. Radievogo Inst.
Trudy Inst. Priklad. Mineral.
Trudy Lomonosov. Inst. Geokhim. Krist. & Mineral.
Trudy Petrograf. Inst. Akad. Nauk S.S.S.R.
Trudy Vsesoyuz. Nauch.-Issledovatel. Inst. Mineral. Syr'ya
Umschau
Univ. N. C. Eng. Expt. Sta. Bull.
Uspekhi Khim.
Vegyi Ipar
Verhandel. Akad. Wetenschappen Amsterdam, Afdeel. Natuurkunde
Wärme- & Kälte-Tech.
Z. Angew. Mineral.
Zapiski Vserossilskogo Mineral. Obshchestva
Z. Wiss. Mikroskop.

OFFICIAL PERSONNEL OF DIVISIONS, 1939–1940

	Art	Enamel	Glass	Materials and Equipment	Refractories	Structural Clay Products	Terra Cotta	White Wares
Trustee	L. E. Barringer	H. G. Wolfram	D. E. Sharp	H. B. DuBois	C. E. Bales	A. F. Greaves-Walker	F. B. Ortman	E. H. Fritz
Chairman	J. P. Thorley	W. H. Pfeiffer	N. W. Taylor	William Malkin	S. F. Walton	C. R. Austin	H. E. Davis	K. Schwartzwalder
Vice-Chairman			W. R. Lester	B. T. Bonnot	J. B. Austin	H. Z. Schofield		
2nd Vice-Chairman	Theodore Lenchner		A. K. Lyle					
Secretary	C. C. Engle	D. G. Bennett	S. R. Scholes	W. H. Emerson	Gilbert Soler	J. H. Isenhour	D. F. Albery	Harry Thiemecke
Society Nominations A.....	Carlton Atherton	B. A. Rice	W. M. Clark	R. B. Carothers	R. K. Hursh	E. W. Knapp	H. D. Callahan	F. P. Hall
Society Nominations B.....	H. E. Marley	G. H. McIntyre	J. T. Littleton	J. E. Eagle	L. J. Trostel	J. E. Rankin	R. L. Clare	J. R. Beam
Division Nominations	P. E. Thornton W. A. Weldon	W. N. Harrison	A. N. Finn U. E. Bowes					
Papers and Program	W. A. Weldon E. de F. Curtis	J. D. Tetrick	W. R. Lester A. K. Lyle	F. E. Finch R. G. O'Meara S. S. Cole	R. S. Bradley G. S. Diamond W. R. McLain E. B. Read	H. R. Straight H. Z. Schofield L. R. Whitaker	H. E. Davis D. F. Albery	R. Russell, Jr. F. C. Henderson J. R. Kauffman
Membership	K. E. Smith	E. C. Aydelott	J. T. Ogden	R. C. Meeker	C. A. Freeman	J. H. Stewart J. H. Grady	J. L. Carruthers	Hewitt Wilson
Standards	K. E. Smith	C. R. Amberg	G. W. Morey		S. M. Swain E. H. Van Schoick	H. C. Plummer		J. H. Koenig
Research	C. M. Harder	R. L. Fellows	W. Weyl	V. J. Roehm	D. W. Ross	R. B. Keplinger		J. R. Beam
Data	E. de F. Curtis	E. C. Dexheimer	A. E. Badger	F. A. Guignon	C. L. Thompson	H. G. Schurecht	E. E. Marbaker	H. C. Harrison
Rules	W. A. Weldon E. de F. Curtis	G. H. Spencer-Strong	A. N. Finn	J. E. Eagle	K. E. Buck	G. H. Duncombe, Jr.		A. M. Hossenlopp
Councillors	Myrtle M. French E. de F. Curtis	F. R. Porter G. H. Spencer-Strong	F. C. Flint E. W. Tillotson	V. V. Kelsey		T. W. Garve F. M. Butterworth		F. P. Hall
Exhibitions	Anna Lane Dixon	*Bibliography* J. E. Rosenberg	R. M. Curts					W. E. Palmer
Industrial Management	Theodore Lenchner				Furman South, Jr.			